A LABORATORY ORIENTED COLLEGE COURSE IN ENVIRONMENTAL GEOLOGY

By

MICHAEL BERNARD LEYDEN

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DEDICATION

To my wife, Margaret, and children, Andrew Parker and Margot Elizabeth, for their patience, understanding and love--not only during the course of this study, but for all the previous summers, weekends, days and nights when the author journeyed on field trips, attended conventions and participated in graduate study.

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Abstract of Dissertation Presented to the Graduate Council of the University of Florida in Partial Fulfillment of the Requirements for the Degree of Doctor of Education

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By

Michael Bernard Leyden

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Chairman: Dr. N. E. Bingham
Major Department: Curriculum and Instruction

Irrelevance of college course content to daily living has been a frequent cry of students. The purpose of this study was to design a beginning course in geology which not only accents the sociological implications inherent in the study of geology, but also presents the learner with the opportunity to solve geological problems by using laboratory techniques.

Review of the literature provided the author with opinions of science educators and geologists regarding the manner in which a beginning course can meet the implied needs of the pre-service teacher, liberal arts major, and pre-service geologist.

A curriculum rationale was designed in which those environmental problems with geological implications are used as an integrating construct to eclectically balance the curriculum building forces of society, knowledge, and the learner.

Five conceptual schemes essential to the study of environmental geology were designed by the author, and used as an aid in

selection of subject material to be included in the curriculum guide. The guide is divided into three parts:

Section A: The Unit Outline

Section B: Behavioral Objectives essential to the attainment of selected concepts, keyed to specific sections of the unit outline.

Section C: Laboratory activities and projects essential to the attainment of selected concepts, keyed to specific sections of the unit outline.

Such a method of constructing a curriculum guide and the use of geologically related environmental problems as an integrating construct for a curriculum rationale, are the unique aspects of this program.

Because laboratory courses consume so much time, the author asked three science educators and three geologists to rate each of the activities and projects as an efficient use of time (ET), neutral (N), inefficient use of time (IT), or inappropriate for the course (IA). Results from the panel of reviewers are parenthetically noted following each activity or project.

CHAPTER I

THE STUDY

Introduction

Scuffing their way across the sod and cement campuses of the nation, students diurnally enter a myriad of buildings to attend courses required by their major, and those courses required in their program of general studies. Realizing the range of interests displayed by the students, departments offer a variety of introductory courses to accommodate student needs.

Physics is a very quantitative science, even at the elementary level, and this explains why the University of Florida catalog lists: PS 120-Elements of Physics; PS 211-General Physics I; PS 215-General Physics with Calculus I.

In contrast, geology is not as exacting at the beginning stages, but a survey of college catalogs would reveal a diversity of introductory courses. These courses fall into the following categories:

1. General Survey--can be physical geology or a physical-historical geology combination offered with or without a laboratory session; or a study of selected topics; for nonmajors.

2. Physical Geology--with or without a laboratory session; for nonmajors.

3. Physical Geology--for geology majors; laboratory usually required.

4. Geology for Teachers--a special course which allows teachers to receive upper division credit for introductory work, and the student may use this course for an advanced degree; offered with or without a laboratory session.

Through the study of science, students attempt to derive the truth. Because there are no prerequisite courses for the first geology course, there is no need to compartmentalize students by their intended major. This would give all students the same introduction to the science, and ease the administrative duties on the geology department by erasing several courses from the catalog.

For years, the triad of students represented by the science major, the liberal arts major, and the education major has been the bane of professors and curriculum committees, i.e., what should be included, and how should the first course in any discipline be conducted when the audience is so varied?

More than any other physical science, geology concerns the observable natural environment, and can contribute a great appreciation of the earth's beauty. Geology has been labelled the ideal vehicle for transmitting scientific attitudes and an appreciation

of the human culture in relationship to the natural environment (45).

If geology is the ideal science, then it is worth doing well. No matter what the intended major of a student, he has the right to receive an honest introduction to the problems, processes, and practical implications of this science, and the use of several introductory courses cannot transmit the same meaning.

Purpose

It is the purpose of this study to design a course in environmental Geology which suits the needs of the liberal arts student, the pre-service teacher, and the potential geologist. Due to the lack of educational research which empirically derives the needs of college students with respect to a discipline, the term, needs, as used in this study, will mean implied needs. Perusal of the literature will determine what is considered by science educators and professional geologists to be the needs for each group of students.

Active participation in a variety of laboratory exercises, and several all-day field trips will provide the student with concrete experience in this course which focuses on the environmental aspects of physical geology.

Definitions

Physical Geology--This is the first course a student would take in the subject. It covers the nature and properties of the materials composing the earth, the distribution of materials throughout the globe, the processes by which they are formed, altered, transported, and distorted, and the nature and development of the landscape (53).

Environmental Geology--This is concerned with society's use of the earth, with the limitations and capacities of the earth, and with earth resources and processes. It is a science that is people-oriented (28).

Laboratory Oriented--This course will focus on the student completing all-day field trips in which investigations are undertaken and quantified. Data from these trips, combined with the observations made in laboratory activities, will cast the student in an active rather than passive role in the learning process.

Needs--The interpretation of "needs" refers to student need for development of his potential abilities, whether he recognizes them or not, for optimum self-satisfaction. They involve both the interests of the individual and the future demands upon the individual (2).

Curriculum Guide--This is a substitute for a formal course of study where desirable content is suggested rather than prescribed. It includes important goals, a variety of activities, and teaching aids from which those best suited to a particular situation may be selected (34).

Objective--This indicates aim, end in view, or purpose of a course of action or a belief; that which is anticipated as desirable in the early phases of an activity and serves to select, regulate, and direct later aspects of the act so that the total process is designed and integrated (34).

Criterion--This refers to a standard, norm, or judgement selected as a basis for quantitative and qualitative comparison (34).

Relevance--This is pertinence to a situation, relation, issue, or concern which for any reason is in the focus of attention; significantly related to the problem at hand, or to the problems with which people are struggling in a given period (34).

Principle, Scientific--This is a comprehensive generalization describing some fundamental process, constant mode of behavior, or property relating to natural phenomena (34).

Experience--This is acquisition of knowledge, attitudes, or skills through one's own perception and participation; or knowledge attitudes or skills so acquired (34).

Problem--This is any significant, perplexing, and challenging situation, real or artificial, the solution of which requires reflective thinking (34).

Concept--This is the simplest pattern which helps us to order the events around us; it includes similar elements and related facts (10).

Conceptual Scheme--This is a relationship between a number of concepts (10).

Behavioral Objective--This is a goal for, or a desired outcome of, learning which is expressed in terms of observable behavior of the learner (61).

Need for the Study

General Statement

President Nixon said in his State of the Union address:

> The great question of the seventies is: shall we surrender to our surroundings or shall we make our peace with nature and begin to make reparation for the damage we have done to our air, our land and to our water (85:56).

Innately, geology is concerned with the study of our environment. Our polluted streams etch the bones of the earth and waves crash against the coasts to alter and shape man's life along the land-water interface. Ever depleting in abundance, our mineral and energy resources build and propel the Gross National Product.

> Our early fathers saw little chance of serious inroads on our national forests for a thousand years. Today, our best timber land is denuded, the natural coverage for many watersheds is no longer present to save the land from terrific flood waters. We are also faced with dwindling stores of coal, iron ore, oil, and other natural resources. Exhaustion of the known reserves of some of them can be expected in a few short years (26:15).

With our nation dedicated to the solution of environment problems in this decade, any course in geology which omits the opportunity to integrate the social implications of the discipline with the learner is missing a rare opportunity for dynamic relevance in the curriculum.

The Pre-Service Teacher

American schools were sitting in a polluted, stagnant cloud of curriculum complacency, but when the heat from the engines of the Sputnik launch vehicle was combined with the warm air emitted by those critics of the unchanging school, the cloud evaporated, and cyclonic curriculum reform brought fresh air to the students who were choking on the status quo. With hurricane force, the winds blew prestigious acronymic curricula into the schools, with science and mathematics studies leading the way. On the eve of the seventies there are at least 241 projects in science and mathematics which are being utilized (60).

Documenting a specific program's popularity is nearly impossible, and the validity of those studies which even report estimated figures is seriously questioned (92). Unable to obtain a student head count, researchers have bent their computer cards in the direction of the classroom teacher. Such studies are not encouraging to those who author the Earth Science Curriculum Project since the data from New Jersey (68, 81), Pennsylvania (36, 81), North Carolina (1), Texas (49), Connecticut (47), Ohio (72, 76), New York (81), as well as national surveys (8, 9, 55, 56, 62, 75) can be summarized as follows:

1. Many earth science teachers have not had any courses from the spectrum of geology, astronomy, meteorology, and oceanography; while the majority of teachers have not had at least one course in each of these areas.

2. Earth Science teachers are more poorly trained today than they were several years ago.

3. Most teachers never take outdoor field trips.

4. Teachers do not express great concern over the fact that they are poorly trained, lack equipment and laboratory facilities, and do not take field trips.

When New York State adopted an earth science course for ninth grade, schools were urged not to offer this course unless a qualified teacher was present, and a group of high school principals said that they would follow that guideline (18, 81). But Romey surmised that whether a teacher was there or not, earth science was being added to the curriculum, and Skinner concluded that the decision for introducing the subject was administrative and that they were not at all concerned about the competency of available teachers (70, 76).

Five years ago it was predicted that one to two million students would be taking earth science courses in the United States during the 1970-71 academic year, and there would be a need for 13,000 to 20,000 teachers (6, 9, 70, 72). Data collected by ESCP for the 1968-69 academic term showed that 841,422 students were taking earth science (25). Because this figure was based on public school enrollments for only 43 states, the authors concluded that when missing enrollments from seven states are added to the private school populations from 50 states, the two million figure will be reached this year. One only has to note how the enrollment in earth science in Texas jumped from 5,000 to 125,000 in one year if he doubts the realism of the projected growth figures (56).

New science programs in the elementary school meet a similar fate in the classroom of the ill-trained teacher. When asked why they do not perform science experiments in their classes, elementary teachers replied that they lack knowledge in the fields of science, they are unable to use laboratory oriented techniques, and fear a loss of self-esteem when they cannot answer the questions posed by the students (41, 87). Raised in a strictly didactic atmosphere, teachers are unable to allow their students to experience the autonomy needed for problem-solving experiments. Teachers fail to realize that, by merely providing an answering service to student questions, they often kill student curiosity (89). In general, teachers at all levels feel uncomfortable in the laboratory situation, and elementary teachers are hesitant to order laboratory supplies despite the fact that their school systems provide adequately for such equipment in their budgets (64, 83).

Overlapping like circles in a Venn Diagram, there are two features common to the new science programs. One circle represents the high level treatment of the subject matter, and the other is the method by which the students are introduced to the subject verse. "Science" has become a verb and is no longer a noun, for it is not only the "what," but there is a strong emphasis on the "how" (14).

Such integration in the curriculum design spawns a twofold teacher-training problem. We not only need those who meet the state certification standards, but there is a demand for men and women who are committed to the laboratory approach around which these new programs center.

Teachers have been trained with an approach which calls for the memorization of facts, and have assumed a role of a teller of facts when they teach. They know no other way to teach. This technique was acceptable for the traditional courses, but does not adequately prepare the teacher for the sophisticated problem-solving methods he is expected to demonstrate while using the new science programs (84).

Analyses of the statements above indicate that the teacher in training not only needs a solid background in subject matter but his studies must also foster the development of a philosophical perception regarding science. It is the function of a beginning course to stimulate the student to perform additional self-instruction. One course cannot promote competency in the entire discipline, but it plays a great role in the formation of an attitude toward the science (48).

Curriculum materials will continue to be produced by loquacious committees, but it is the classroom teacher who has the final say as to what shall be taught and how classes will be conducted. Success of any course depends entirely on the teacher, and if he adopts the ESCP materials but not the underlying philosophy of the program, the student is betrayed (24).

Changing teacher behavior is a difficult but not impossible task. Success has been registered in cases where teachers have participated in institutes designed to increase their subject-matter competence and acquaint them with the new curriculum programs (65,93). Burnett is more pessimistic regarding the ability of an institute to change teacher attitudes, and would agree that it is more efficient to mold the behavior of the pre-service teacher rather than laboriously reshape the perceptions of the in-service teacher (12).

Desired instructional techniques were outlined in a survey of 123 colleges having earth science teacher programs. They include:

1. extensive field experience,
2. proper equipment and physical facilities,
3. laboratory sessions designed to use a process approach,
4. a laboratory program where each activity leads to logical operations, and
5. student-centered instructional programs (57).

Provided that teachers really do teach as they are taught, the instructional techniques suggested above will have a tremendous impact on the secondary school programs.

Excellently summarizing the need for active student participation in their subject field, Combs said:

> In order to become effective teachers, teachers-in-training need to experience subject matter, to wade around in it, to make mistakes in it, to be intensely and personally in interaction with it, till it becomes a part of their very being. They must feel they are participants in it and contributors to it (15:50).

Probably the most interesting study relating the growth of secondary school earth science to the need for realistic teacher training was conducted by Orgren. He traced the history of earth science in secondary schools from 1830 to 1970, and found that for a long time geology and physiography were strongly entrenched in the program of studies. Then interest began to meander toward the other physical sciences which were more applicable to the in-door laboratory situation: particularly, physics. The Committee of Ten urged the use of out-door field trips to sustain geology in the curriculum, but the teachers had been prepared on a notebook fattening diet of words like tarn, horst, trilobite, and delta, and their training lacked the essential proteins provided by field studies. With such a vicarious introduction to the discipline, student interest died of malnutrition, and geology was interred in the course of studies. Let this serve as a warning to all those teaching geology, lest history repeat itself (66).

The Liberal Arts Student

From the above discussion it is apparent that the literature abounds with words penned by those who are concerned with the training received by the potential teacher. The case for the liberal arts student is equally well documented.

Each department on the campus should realize that they have a major obligation to those students whose interests lie in other fields (42, 69). The potential of a course in geology to the liberal arts student is immeasureable.

> No citizen of tomorrow will be able to exercise his obligations without realizing that our civilization and economy depend on abundant minerals and energy; that our survival in a sense, may depend on how well each citizen understands the hazards of tampering with our environment, particularly the solid earth (6:9).

Geology allows the student to witness the interplay of biology, chemistry, and physics--a discovery which may spark further interest in these fields, and a basis for understanding his environment (59). As a citizen in our society he will be asked to vote on topics which will influence the economic, military, and political use of our natural resources. The objective of science for the liberal arts student is to equip him to read freely and understand current science problems to a reasonable degree (39, 42).

Content analysis of newspaper and periodicals reveals that the lay public is being bombarded with an increasingly large amount of data concerning scientific and technological discoveries (50, 96). These research studies are used by their authors to describe the

need for citizens to know a certain number of scientific principles, terms, and to possess a minimal number of mathematical skills if he is to comprehend such printed reports. While admitting that knowledge of facts, principles, mathematical skills would facilitate the reader's understanding of scientific accomplishments, it seems that the researchers are missing an important point.

Many scientifically knowledgeable persons pass over news reports concerning science, turn off televised space shots, and ignore other important publicized happenings in the fields of science. They do so because they are unable to see how such events relate to themselves. Students must develop an attitude toward science and its application to everyday living. Knowledge, as such, is not what is needed to understand the scientifically toned news releases. What is needed is a willingness on the part of the citizen to become involved with the topic. When a person becomes interested in a problem he will dig into it and acquire the necessary background needed to understand the situation (37).

Engendering an interest in a continual study of science is the responsibility of the classroom teacher, and is directly related to the methods used to conduct the elementary courses. College teaching should be dynamic, and the student stimulated by real problems dealing with relevant topics. Laboratory studies, field work, and independent research projects accomplish this end. There is no need to water down the elementary courses. They should deal with high level concepts, and be pitched at a level coincident with the student's background (37).

Students do not have to be coerced into such study as they are quick to voice their favor for courses which involve field work, conservation study, and other relevant topics (21, 32). Courses of this type allow a student to investigate man's geological environment and offer him the opportunity for a closer liaison between the scientists and the general education student.

Perhaps the most poignant words were written by Carl:

> In the teaching of all branches of natural history, there is a strong tendency to make classification so prominent that the student leaves the subject with the idea that ability to recognize a series of forms, and to give to each, without hesitation, some unpronounceable and meaningless name, is about all there is of science . . . (13:48).

The Geology Major

With geology absent from the high school curriculum for the major part of the nineteen hundreds, it is not surprising that a study in 1950 revealed that virtually all students were totally unaware of the vocational and avocational opportunities offered through the study of geology. Their factual knowledge of the subject matter in this science was almost nonexistent (11).

About 15 years later a survey of 1,200 geology majors from 400 colleges and universities revealed the importance of the introductory geology course. When asked why they were majoring in geology:

> 28 percent said it was due to the influence of their first course or courses in geology,

48 percent did not decide to major in the science until they were in college, and

41 percent claimed that the influence of one teacher was an important factor (78).

There is a strong piece of irony involved in the data presented above. One gets the impression that departments feel courses for nonmajors are just a necessary evil, and it is a waste of time to take a scholarly professor and put him in charge of an introductory course (77). Yet the study showed that 48 percent of the majors did not select geology as their field of concentration until they had received stimulating instruction in the elementary courses. They were converts to geology--metamorphosed liberal arts students. It appears to be impossible to make separate courses for geology majors and liberal arts majors since so many of the former are spawned from the latter.

Fortunately, there are many who recognize the importance of dynamic teaching in the beginning courses, for the enthusiasm displayed by the professor is contagious (46, 79). Upper division courses will never be filled unless students are motivated toward further study from the quality of instruction in the elementary courses.

Extensive field work, open-end laboratory sessions, allowing students to choose their laboratory problems, and more creative teaching techniques than lecturing are some of the methods advocated to recruit new geology majors and retain those who already have chosen this science as their major (40, 71).

Because we are living in an age of specialization, some may regard the remarks of Foose as a step backward for the training of majors. He urges geology majors to take more liberal arts courses to strengthen their overall education (29). With so many science grants being funded by nonscience foundations, the major in science must be able to communicate with the nonmajors.

Summary

Personal beliefs held by geologists and science educators concerning the needs of various types of students, and how an introductory course can meet these implied needs have been supplied by a review of the literature.

Those concerned with teacher education believe that teachers-in-training need a laboratory oriented course for they must have firsthand experience with the subject matter, develop the skills and techniques used in such study, and most important, begin to develop an attitude concerning the spirit and philosophy that is involved in the science. With such a background he will be able to conduct courses in earth science in the manner desired by the authors of the new curricula.

Liberal arts students are taking one look at the science of geology, and those concerned with the general education student think that his first glance at the discipline should allow him to view an exciting panorama of this subject, and its important practical applications. The geologic mural painted by the teacher should serve to motivate the student to perform additional study in the discipline.

Guardians of the preprofessional geologist ask that his education include practical study which relates to his liberal arts training--concerns relevant, topical problems, and involves experience in field work.

Spokesmen from each school--liberal arts, education, and geology--use different words to describe their feelings, but it is apparent that they are asking for the same thing: a laboratory oriented course in environmental geology.

Assumptions

Three assumptions underlie this study:

1. the problems posed by the pollution of our environment and wanton destruction of our natural resources demand that the public be made aware of the consequences of such desecration.

2. active participation by learners is preferable to passive reception of the content to be learned (82), and

3. transfer of learning occurs more smoothly if the learner can discover relationships for himself, and if he has experience in applying principles of relationships within a variety of tasks (82).

Problem

Construction of a curriculum guide for a one-semester course in environmental geology which focuses on a laboratory orientation to the discipline is the desired product of this study.

Specifically, this project will result in a study guide that will:

1. contain a course outline for the subject,
2. list conceptual schemes, concepts, and behavioral objectives to be derived from the course, and
3. contain specific laboratory activities.

Method

Obtaining the desired product of this study will require three steps:

1. developing a curriculum rationale,
2. examining contemporary thoughts regarding curriculum planning in science education, and
3. selecting the course content and sequence.

Developing a Curriculum Rationale

Empirical evidence regarding curriculum development is lacking, thus the topic is open to debate. A literature search will bring to light those ideas which are currently prominent.

Society, knowledge, and the learner form a curriculum triangle according to Saylor and Alexander (73). Hass and Wiles also have a curriculum polygon, but theirs is four-sided--social forces, knowledge, learning, and human development (38). Paul Dehart Hurd has a more radical idea concerning curriculum development (44).

After a literature search has been completed, the author will extract what he feels are the most important cornerstones on which to build a curriculum.

Curriculum Planning in Science Education

Science curricula in the secondary schools are designed around certain conceptual schemes. Component concepts of these schemes are developed by having the student perform certain behavioral objectives. These terms have already been defined, but the author will examine the literature in an attempt to determine why science educators believe such an approach to curriculum planning is important.

Selecting the Course Content and Sequence

By definition, conceptual schemes unify concepts, and by formulating a small number of conceptual schemes, the curriculum architect will be provided with a blueprint from which he can determine the expanse of his curriculum structure. Other factors which will influence the selection of course content will be discussed next.

Limitations

1. The author's training has provided him with a perception and philosophy concerning the science. This image of what is taught and

how it should be taught will have a great influence on the development of the course.

2. The time restriction of one semester will cause certain topics of study to be omitted.

3. A course in environmental geology should be designed to take advantage of the geological location of a specific campus. This is not possible because the author has not signed a contract for the 1970-71 academic year.

Evaluation

Selected by the author and his committee, a panel composed of three science educators and three geologists will be asked to comment on the structure of the course. The names of the panel members will be listed in Appendix A.

Duties of the panel members will be threefold:

1. They will be asked to examine the conceptual schemes and comment on the appropriateness of such schemes for a course in environmental geology. The reviewer may add or delete conceptual schemes to the list composed by the author and his committee.

2. The panel members will be asked to comment whether the concepts stated at the beginning of each unit of study are essential to the development of the conceptual schemes. They may add or delete concepts in unit of study.

3. Each activity and project will be rated by panel members. Laboratory courses consume a large amount of time, and the author is interested in gaining some information concerning the types of activities and projects that should be used in such a course. These activities will be marked as an efficient use of time, neutral, inefficient use of time, or inappropriate for a beginning course. Tallies will be parenthetically noted after each activity in the curriculum guide. For example: (2 ET, 1 N, 2 IT, 1 IA) is interpreted to mean that two panel members thought the activity was an efficient use of time (ET), one was neutral (N), two reviewers thought it was an inefficient use of time (IT), and one thought it was an inappropriate activity (IA). The opinion of the six judges will aid the author and the reader in his decision to include or exclude an activity in the presentation of the course.

Chapter V will include a report from the panel members regarding the conceptual schemes, concepts, and any other comments they may make (91).

Organization of the Dissertation

Five chapters and three appendices will be used in this report

Chapter I	The Study
Chapter II	Developing a Curriculum Rationale
Chapter III	Curriculum Planning in Science Education
Chapter IV	The Curriculum Guide
Chapter V	Implications of the Study
Appendix A	Names of the Panel Members
Appendix B	References Used in the Curriculum Guide
Appendix C	A Sample Field Trip Guide

CHAPTER II

DEVELOPING A CURRICULUM RATIONALE

Introduction

Galileo would not know what to make of it: the curriculum pendulum. The Florentine gentleman and Linceo scholar who gained fame by clocking pendulum oscillations in the physics laboratory would be at a loss to explain the behavior of the pendulum in the laboratory of the curriculum specialist.

Propelled only by gravity, the tick-tocking bob of the physicist gives rise to replicable experiments. But the curriculum pendulum is acted upon by a variety of accelerating forces and the only replication on which the educator can rely is that the plane of oscillation will shift.

Data collected from historical observation of curriculum momentum identifies various focal points of curriculum design: the disciplines, child experiences approach, life needs curricula, society oriented, occupational job analysis, and many others. The major forces affecting curriculum motion are society, learner, and knowledge. Responding to the influence of these vectors, the curriculum trend circles like a Foucault Pendulum--time being the catalyst which causes the weight to return to any one curriculum theme.

This chapter seeks to develop a curriculum design by examining the literature regarding the major curriculum forces, and analyzing the importance of these forces in making curriculum decisions. This is not an easy task because most of what is written with respect to curriculum planning is aimed at the elementary and secondary schools, and there is a dearth of guidelines for those who intend to mold a program for the college level.

College level curriculum planning is left to departments and individual faculty members. They decide what shall be taught and the methods used to conduct the course. Very little consideration is given to the role of any one course with respect to the total educational program of the university (95). Administrators dare not tread on the sacred ground of a professor's course outline, and only in cases of extremely radical behavior would the teacher be made to bear the weight of the legal and extra-legal curriculum forces listed by Saylor and Alexander (43, 73).

Societal Curriculum Forces

Why is Society Important?

Spilled on tons of paper, gallons of ink spell endless lists of platitudinous remarks regarding the purposes of American education. Some writers, such as Dewey in Saylor and Alexander, retort garrulously about the values of education in a democracy. To wit:

> The primary business of education is effecting the promises of American democracy, is to guard, cherish, advance, and make available in the life of coming generations the funded and growing wisdom, knowledge . . . (73:126).

Others wax poetically:

> The school can spring gracefully from the active soil of the community and its fruits will return to enrich that soil (80:37).

Oratory of this nature is not just aimed at the elementary and secondary schools. Colleges are becoming increasingly aware of their role in providing relevant education. Words to this effect annually weight the publication of the Higher Education Association, a division of NEA.

Unlike the situation which exists in totalitarian countries where the values of the state are placed above the purpose of individual development, American schools are established to insure that the students are able to face the problems arising from their interaction with our complex society (17, 38, 73). Clearly, one cannot disregard the societal influences if they are to meaningfully educate.

Science and Society

Reagents such as the population bomb, the knowledge explosion, advances in communications, increased amount of leisure time, and technological advances which create occupational obsolescence affect the magnitude of the force which society exerts on the curriculum. Scientific discoveries have incubated all of these reagents. Society influences the curriculum and science influences society.

> Hence, the curriculum basis of social forces leads to a consideration of the need for the student to understand the relationships of scientific principles to the environment of which he is a part (17:10).

"Blue Collar Science" was the term used by Vineyard when he recently stressed the importance for teachers to focus on the pragmatic study of social problems by using scientific inquiry techniques. Deterioration of our environment is such a problem, and this study of this problem is no less important and requires equally significant mental processes as the study of an Apollo flight (88).

Society-Curriculum Interaction

Should the curriculum dictate changes in society, or should society dictate the content of the curriculum? It is almost impossible for the schools to change society, per se. Consider the reaction such courses as sex education, Communism, and even driver education have had. The lay public are not content to let a handful of educators make curriculum decisions which infringe on cherished beliefs. Because discussion of such relevant topics is totally discouraged by the public, the society based curriculum has often been accused of promoting the status quo (73).

Society does not only have a negative influence on the curriculum. Courses are added to the schools and colleges with regularity and without any fanfare--particularly if they deal with the preparation of a student for a vocation. But students say that this is not enough.

Professors and departmental curriculum committees may be protected from the legal and extra-legal curriculum forces, but they are quite vulnerable to the totally illegal force now present on the college campus: the protesting collegian armed with rocks and guns.

These students are not content with the addition of a dozen new engineering courses to the college catalog. They want courses that deal with societal problems. To them, a curriculum based on societal needs does not promote the status quo, it promotes student involvement with relevant education.

Administrators are caught in the middle. At the high school level they may want to add a course in sex education to the curriculum, but the parents protest. At the college level, the students protest the fact that the power structure will not meet their demands for new courses.

Besides the problem of one pressure group convincing another pressure group of the importance of a curriculum decision, there is a more fundamental question involved with the society oriented curriculum: is it practical to study current problems and interest when students will have an entirely different set of problems to solve in 10 or 20 years?

Supporters of the societal approach to curriculum building are quick to point out that, by studying current problems, students will learn how to approach any problem they may face in the future in a rational and constructive manner (30).

Knowledge as a Curriculum Force

Background

Nothing popularized the term, structure of the discipline, more than the Woods Hole Conference in 1959. This term has been subjected to various definitions by professional educators (19, 30, 73). To the layman, the term, structure of the discipline, might be

colloquially referred to as "stuff." "You know, the stuff they teach in the schools."

Never in history have the schools been without "stuff." The Greeks studied the Seven Arts--the trivium and the quadrivium. For years the public considered the goal of the American school was to teach the three R's, but the high school of the 1970's conducts such diversified courses as Sewing II, Auto Mechanics, and Advanced Physics. The University of Florida catalog lists hundreds of courses--from Swahili to Chaucer. Trivium, the three R's, Sewing, and Swahili: all stuff--what is taught.

No singular item is so directly tied to the schools as the transmission of knowledge. This task is the aorta in the stream of school functions, but no curriculum basis incites more incendiary passion among scholars than discussion relating to "stuff."

Controversy in science education pivots about the question of whether the school should teach knowledge for the sake of knowledge, or if it is the primary role of the school to allow students to experience how knowledge in the disciplines is discovered and used. Battle lines are drawn between the researcher in the disciplines and the science educator. An emotional, name-calling conflict ensues.

Researchers in the sciences decry the educator and question his academic prowess. The educators reply with equal anger, and present their case: schools must consider the abilities of the learners when they select their curricula, and choose subject matter which is relevant to society. If knowledge alone were the goal, the

student could stay home and learn facts--schools would not be needed. The student is not a fact machine, and such totally knowledge-centered curricula focus on the metamorphosed three R's--read, remember, and regurgitate.

Pros and cons of the content approach and the process approach will be discussed in this section.

Content Approach--Pro

Sputnik's influence on science course content is legendary, but there were factors other than the orbiting of an artificial satellite which caused the discipline approach to surface as a forte in the curriculum reformation of the sixties:

1. the knowledge explosion caused educators to be more selective in the choice of material taught--eliminating the trivial, and emphasizing the significant,

2. scholars from the disciplines were called into conference with the curriculum specialist and the classroom teacher, and

3. advances in learning theory revealed that subject matter could be placed at grade levels where it was previously thought to be too difficult (19).

Studying the structure of a discipline has several advantages:

1. by enhancing memory, it facilitates the use of knowledge and the transfer of learning,

2. provides a framework from which newly formed knowledge may be added and older, inadequate concepts may be subtracted, and

3. since structure of the discipline is a basis for organizing knowledge for the scientists, the curriculum maker's task of selecting content which truly represents the discipline is facilitated (73).

Other than the factors listed, one of the most influential factors which popularized the subject centered approach is human inertia. This curriculum design is one which:

1. has always been used in college so the teacher feels secure when using this approach,

2. satisfies the public image of what education should be like, and

3. is easily adapted to textbook organization, curriculum planning and evaluation (73).

Content Approach--Con

Criticism leveled against the subject centered approach in curriculum design is precipitated by several factors:

1. it does not give proper consideration to the learner since the student is not provided with any personalized meaning to the value of the knowledge,

2. it does not give proper consideration to the relevance of knowledge to society because the student works within a restricted framework of the discipline and cannot test his knowledge in a variety of life experiences, and

3. it is an undemocratic way to learn because students have no voice in what shall be studied and how it will be structured. Information is "discovered" on the page of the text. The author has not only decided what shall be taught, but has decided that the material on page 36 should be presented after the material on page 35 and before the material on page 37. This might be a logical arrangement to the textbook expert, but it probably does not fit the student's cognitive perception of the subject (54).

Goodlad detected another fundamental weakness in the approach--a lack of direction.

> The lack of stated aims for education has virtually forced curriculum project groups to turn to school subjects for the determination of their ends and means. As a consequence, ends and means frequently become entwined: to learn the subject is the end; learning the subject is the means. There is no external criterion against which to judge the effectiveness of the new and old (35:94).

Process Approach--Pro

Opposing the content approach design are those who insist that the emphasis in science teaching should be upon the way in which man uses his knowledge rather than the knowledge itself.

Rather than being the destination, knowledge becomes a vehicle for solving future problems when students use the process approach. Learning is perpetual, and does not end when the grade of a course is recorded or when the degree is granted. The process approach facilitates transfer of learnings to enable the student to examine new problems, and find personal meaning in the discipline (17, 67). Considerations of society and the learner with the problem-solving process allow the process approach to be acclaimed from a moral standpoint (54).

Process Approach--Con

Resistance to the process approach in curriculum design is offered on two fronts: human limitations and physical limitations.

1. Human limitations:

Teaching has always been a telling procedure, and the ability to teach has always been equated with a teacher's prowess to filibuster. Educated in a didactic atmosphere, it violates a teacher's perception of the learning process to do anything else but lecture. To encourage students to criticize, question, investigate, create, discover, and to think inductively is a completely foreign approach for many teachers (35).

2. Physical limitations:

Shortage of money and time puts severe restrictions on the successful implementation of process approach curricula. Even when a teacher is willing to experiment with such a curriculum he must first convince the power structure that the laboratory equipment needed for such study is a judicious budgetary expenditure.

Even if a teacher could be saddled with enthusiasm and loaded down with equipment, he must leap one more hurdle--the time limitation. Governed by the semester hour system or the Carnegie Unit, classes are about 50

> minutes in length, thus limiting the amount and quality of the investigations performed. Fundamental to the time factor is the basic problem that students cannot possibly discover all the things they should know in every discipline no matter how much time they were given (30). The lecture method of presenting subject matter is tremendously efficient with respect to the amount of time it takes to cover certain topics (3).

While other criticisms are leveled against the process approach of teaching, none are more effective in diminishing the enthusaism for the new science curricula than the two items discussed.

Summary

Process and content sects arise from stated beliefs regarding the manner in which study of a discipline should be conducted. These beliefs are allied through various pedagogical terms--terms which lack precise definitions, and thus place such allegiances on seismic ground. Some of the terms used are: process oriented, inquiry method, laboratory oriented, structure of the discipline, content approach, knowledge centered, discipline centered. Even when formal definitions are available it does not assure a common goal to any one group since everyone has their own perceptions of what various terms mean.

Advocates of the knowledge centered approach might arrange and use the terms in this manner:

1. knowledge centered or content approach,
2. structure of the discipline,
3. laboratory orientation, and
4. inquiry method or process centered.

Acquisition of knowledge is the goal of this approach, and to achieve this end, these scholars say that one must examine the structure of the discipline. This requires the students to use laboratory techniques and to behave as a scientist to uncover the desired knowledge. These laboratory experiences are thus inquiry oriented.

Proponents of the process approach might reverse the order of the importance of the items listed above. Their goal is to expose the students to the methods used by scientists to uncover knowledge by using the inquiry method in laboratory situations. The students learn the structure of the discipline and subsequently derive knowledge of the discipline.

Both groups may go through the same procedures, but the emphasis of the study is different. Knowledge is the goal in one school of thought and the method of study is a byproduct. Those who favor the process approach want the student to learn to ask questions and to inquire. By doing so they gain knowledge, but this knowledge is secondary to the methods used to question, criticize, and analyze problem situations. In this approach, the method is important, and the knowledge is a byproduct.

Krug believes that there is no reason why animosity should exist between those who favor content or process approaches to curriculum design. There are places for both themes in every subject (51).

The Learner as a Curriculum Force

Introduction

Students limp from the educational battlefield--mentally wounded by schrapnel of the knowledge explosion, and physically impaired from the pressures exerted by the heavy societal demands placed on the curriculum. Caught in a crossfire between those who advocate a knowledge centered approach and those who favor a societal orientation for the curriculum, the student retreats from the front lines of battle to the sick bay--only to again be flown as a drone when the next sortie begins.

Discussion of the roles played by knowledge and society with regard to curriculum matters has been carried out in this chapter. Attention is now focused on the learner as a curriculum force, and any consideration of the student in curriculum planning must be weighed by two traditional factors: philosophical considerations and psychological considerations.

Philosophical Considerations

Charges of immorality are leveled against the subject centered curriculum because the knowledge is already determined and sequentially packaged into a textbook. Socially oriented curricula also come under attack:

> "What," asks the catalog of a certain private school, "is the domain of the curriculum?" And it answers that the domain of the curriculum is not a nation, as many Europeans think; not a state as some Americans think; not a municipality or school district, as other Americans think; not a school as most private school men think; not as a classroom as many teachers think. The domain of a curriculum is one student (5:378).

MacDonald seconds this motion. He stated that the curriculum must allow the student to gain personal meaning from the knowledge. There must be opportunity for the student to interact with the teacher, the discipline, and his fellow students. Although many of the new curricula are content oriented they allow the student to study many cultural resources and thus give the student an opportunity for personal understanding of knowledge. These curricula are considered highly moral (54).

Psychological Considerations

Two ways exist for adapting information from the discipline of psychology to curriculum planning:

1. research concerning learning theory and
2. research from the field of human growth and development.

Research concerning learning theory

Piaget's theories on learning are flooding the reservoirs of curriculum thought for students of the early elementary years, and the works of others are carefully considered at higher levels of schooling. There is almost a total absence of empirical research regarding the learning process as it applies to students at the college level (4).

Research studies concerning the value of using inquiry methods or process approaches or problem-solving techniques in science courses indicate that the use of such curriculum designs result in a student who:

1. was more highly motivated than those students in the traditional courses,

2. was a better critical thinker than those students in the traditional courses,

3. retained major concepts better than those students in the traditional courses, and

4. retained facts more poorly than those students in the traditional courses (7).

Use of a laboratory oriented course in environmental geology will allow the author to take advantage of what little information is available regarding the possible effects of such a curriculum design.

Research from the field of human growth and development

Failure to learn will cause the student to suffer personal adjustment problems, and the presence of personal adjustment problems often causes a decay in classroom performance. These two areas of psychological considerations are interdependent.

Attention is immediately focused on those infinitely thick piles of needs that are published by many psychologists whenever educators consider the student's relationship to curriculum planning, but this method of building a curriculum has been attacked by MacDonald.

> A person is not to be thought of as a bundle of needs, or interests, or unique purposes that can be directed or guided or developed to someone's satisfaction. We, none of us, have yet the all-knowing power to prescribe what is best for each person . . . (54:38).

Comforting as it may be for some teachers to have a list of needs to guide their lesson planning, there are dangers inherent in such an approach. Learning is not to be considered simply a matter of mastering a series of tasks or jumping through the hoop at the command of the teacher. Also, the tasks to be performed vary from person to person and in time and space (27).

Reflections of the curriculum triangle are provided by a list of needs prepared for college students.

1. Social basis:

   the student needs to achieve a sense of responsibility toward the society in which he lives.

2. Knowledge basis:

   the student needs to relate himself to the new knowledge he is discovering.

3. Psychological basis:

   the student needs to learn to develop his new autonomy from his parent and to discover who he is, where he wants to go, and what he wants to be (31).

Lists are always attacked for being too specific or too general. No matter how valid and complete a list of needs may be, it is impossible to account for the value that any one student places on any one need. Because of the inadequacy described, a search for the ultimate list of student needs will be abandoned. The author believes that it is more efficient to concentrate on the most pressing need of all students as a force in curriculum planning. Combs describes this need as the drive to develop an adequate self (16).

Perceptual psychology is a school of thought which attempts to view the student from an internal frame of reference. It is the thesis of this approach which states that people do not react to the facts as others see them but respond to the situation because of the perception of the facts (16).

Designers of the curriculum must ask themselves how the subject appears to the student because every student must create and organize knowledge for himself (27). All students may be able to define density, but each has a personal concept of what this term really means. Any experienced teacher knows that students constantly question the worth of learning almost anything. They are really asking the question: "What good is this knowledge to me?"

Motivation has been a concept around which teachers have always rallied. A tenet of the perceptual school is that motivation is an internal trigger and that no one person can motivate another. What people can do is to manipulate the environment surrounding a person so that he perceives the new situation as self-enhancing (16). Because people are always striving to enhance themselves, no one is ever unmotivated. The problem is to get the student to perceive

any situation differently--to view the goal as self-enhancing (16).

Viewed in the teaching situation:

> Children (and adults) often try to escape learning tasks that they consider beyond their abilities and will work beyond the requirement on those in which they perceive a chance of success . . . . If he is presented with situations and encouraged to discover and test his own answers (rules, generalities, and principles),- the pupil is more likely to become interested in the subject than if the teacher or textbook presents the rules, however clearly (30:33).

Consideration of the student as an individual is of utmost importance to those who advocate the perceptual approach to teaching. Umstattd said that, by observing seven parameters, teachers can weigh student individuality. These factors include background, attitudes, curiosity, interests creativity, mental power, and drive (86).

Success of any curriculum design ultimately rests with the quality and quantity of interaction which occurs between the teacher and the learner. This is particularly true of the perceptual approach, and Combs devotes an entire chapter of his book to the importance of the teacher to the program (16).

Summation

Eclecticism

Patterns of curriculum development differ from one another only in the priority given to the referents used to develop a specific instructional program. Curriculum building is not an either-or proposition since no one design has all the answers.

Eclecticism appears to be the only rational route in the tiring task of planning a curriculum guide.

Environmental Geology and the Curriculum Triangle

Relating the triad of curriculum forces to the curriculum guide will be accomplished in the following manner:

1. Society
   a. The theme of the course is man's use and misuse of his environment. This will be considered to whatever degree possible for each unit of study.
   b. Local geology will be discussed at length. Is there sufficient ground water, what are the flood problems, what are the mineral resources of the area?
2. Knowledge
   a. What are the important conceptual schemes on which geology is grounded?
   b. How does geology relate to the other sciences?
   c. What material is essential for students to have so that they may elect other courses in geology?

3. Learner

a. Students will have many opportunities to experience laboratory and field activities with the subject.

b. There are many projects listed for students to choose topics for individual study.

c. Student interaction with the teacher and fellow classmates will be encouraged at all times.

Eclecticism is the only design acceptable for this study. Even the title of the dissertation dictates such a plan:

"A Laboratory Oriented . . . "

such an approach allows the learner to examine the discipline through inquiry methods.

". . . College Course . . ."

the knowledge of a specific subject is presented to the student.

". . . in Environmental Geology"

by definition, such a subject is very much concerned with society.

CHAPTER III

CURRICULUM PLANNING IN SCIENCE EDUCATION

Introduction

Daily acquisition of new knowledge in the sciences has caused problems on two fronts. Scientists are faced with revising their formulae, changing their facts, and amending previously held concepts in the light of newly acquired information. Science educators noc only face the problems of the scientist, but must also decide how the new information will affect the curriculum.

Renovation of the curriculum is more than just the addition of new information to the textbook. Realizing this, the national curriculum projects have built their courses around a conceptual scheme approach. These schemes not only represent the most stable components of scientific knowledge, but provide a means for incorporating what is new in science, thus keeping the courses from stagnating.

Lower on the learning ladder than conceptual schemes, concepts and behavioral objectives are also important ingredients used by curriculum designers. A discussion of these pedagogical terms follows.

Behavioral Objectives

Introduction

"Child and the Curriculum" was the title of the first education course required of all students at Brockport State Teachers

College in 1958. The author was a student in this course which was designed to teach students how to construct lesson plans. By the end of the first week of instruction the students realized that the term behavioral objectives was about to become a household word.

Behavioral objectives were around long before 1958. The Boy Scouts of America were founded around the turn of the century, and their manual has always been known for informing a Scout exactly what he is expected to do to earn various pins and badges. In 1970, the role of behavioral objectives in lesson planning is still being stressed.

Whether they were written in a Boy Scout manual in 1915 or in a teacher's lesson plan in 1970, there are reasons why behavioral objectives have had such a lengthy life span. Before these reasons are discussed, it is necessary to define the term.

Defining Behavioral Objectives

Simply stated, behavioral objectives are those desired goals to be derived from a lesson or activity and are expressed in terms of observable behaviors of the learner. The reader is reminded of Carleton's article where he stated that science has become a verb and is no longer a noun (14). When writing behavioral objectives, verbs are used to describe the desired behavior of the learner. The new science curricula and behavioral objectives are inextricably linked.

Learning has been defined as a change in behavior, and when writing objectives the first step is to choose the desired behavior. Some of the verbs commonly used to do so are: selects, challenges,

reads, rejects, predicts, criticizes, organizes, synthesizes, specifies, and compares (22). Some of these behaviors call for higher cognitive skills than others. Using verbs to describe learning behaviors, Sund listed five groups of tasks. From simple to complex:

1. imitating, duplicating, and repeating;

2. recognizing, identifying, remembering, recalling, classifying;

3. comparing, relating, discriminating, reformulating, illustrating;

4. explaining, justifying, predicting, estimating, interpreting, making critical judgments, drawing inferences, and

5. creating, discovering, reorganizing, formulating new hypothesis, and questions (82).

Verb choice is only one part of writing behavioral objectives. It is important that the final objective be practicable, psychologically sound, attainable by the majority of learners, and can be universally applied (90).

As a final criterion, objectives should be designed for a specific group. Regardless of how many objectives have been stated by others, the classroom teacher must establish those goals which he believes essential to the study of the topic (52).

Rationale for Behavioral Objectives

Presence of behavioral objectives in a lesson plan provides the teacher, the student, and the administration with a security blanket. Teachers can answer administrative queries, and the administration is able to communicate with the parents because they can define the structure and the goals of the course. Students reap the rewards of behavioral objectives because they know what is expected of them. They are then able to identify their progress as they move toward the goal, and they realize when the goal has been achieved (23).

Test construction is facilitated by using specific objectives to plan teaching activities. Very often, test items are simply the statement of the behavioral objective in question form. No evaluation section will be included with this curriculum guide because most of the questions would simply be restatements of the behavioral objectives.

Behavioral objectives make their final contribution to lesson planning when test results are examined. Three questions must be asked of each test item:

1. Was the objective appropriate for this group of students?

2. Were the activities designed to foster the behavioral objective efficient in achieving their goal?

3. Was the test item fair and clearly stated? (23)

Concepts

Introduction

Some of the objectives in the curriculum guide were simple responses to a direction. For example, the students were asked to examine a topographic map, and record the map scale. The student reads the map scale from the bottom of the map and records it. Other objectives require a higher order of mental activities. When the student is asked to compute the area of a topographic map in square miles he must interpret the meaning of map scale, and use it to solve a problem. He is no longer dealing with an inert fact but is manipulating a concept. When several related concepts are integrated, they form the basis for conceptual schemes.

Concepts thus exist on a continuum between facts at one extreme and conceptual schemes on the other.

Concepts: What are They?

Formal definitions of the term, concept, abound. Good (34) lists three definitions as does Glenn (33), but Brandwein gives the reader a working definition:

> You and I do not attend to everything. We tend to ignore the insignificant, we concentrate on what is significant to us, or we disregard what we do not see as fitting our purposes. We tend to see the scene before us as a whole, in terms of relationships, that is, in a pattern . . . . We organize the scene we are watching, and try to see it as a pattern. Our thought processes seem to call up the simplest pattern describing the scene. This simplest pattern which helps us to order the events around us is a concept. A concept is a reduction, in a sense, of events to a recognizable configuration (10:110).

Because an observer has a concept of mammals, sedimentary rocks, and vegetables, he can classify or discriminate between cows, shales, and carrots. He can also associate shales, sandstones, and limestones into a group called sedimentary rocks; and cows, horses, and dogs with a group called mammals. Such classificatory concepts help the learner to discriminate, associate, or combine (44, 82). Mathematical relationships such as density and force are called relational concepts, while those concepts which represent a way of doing something are known as operational concepts. Affective concepts deal with attitudes such as curiosity or apathy (44).

Concepts: Why are They Important?

Like carcinogenic tissue, facts are spawned in science classes and may be considered cells of knowledge which migrate to the brain at an uncontrolled rate. Without processes whereby these facts may interrelate and build upon each other to form healthy concepts, they soon contaminate the entire organism. Concepts provide the individual cells of knowledge with nucleus which regulates the rate of factual growth and brings order to the sprawling knowledge system. This nucleus prevents facts which do not fit the growth pattern from entering the cell wall. Bulky facts are dehydrated, and only the important parts are integrated into the growing system. The result of such controlled maturation is a product which brings order from chaos, and provides the student with mobility to explore the unknown because he is armed with meaningful subject matter.

Making subject matter meaningful is no slight task for concept attainment is a personalized matter. This is one of the most significant ways in which concepts differ from facts. Facts are public

knowledge, while concepts must be internalized and become the personal possession of the learner. Each learner might define density as mass divided by volume, but this relationship has a different meaning to everyone.

Internalization of subject matter means that it is impossible to teach concepts, per se. The facts which contribute to the concept can be taught, but the student must knit the concept into his perceptual pattern of knowledge.

Manipulation of the teaching environment is thought to enhance the learning of concepts. Lectures, drill, individualized work, laboratory sessions, field trips, films, and student-teacher interaction all contribute to this cause. With such a multi-media approach, the learner is introduced to the concepts in a variety of situations which help him extend his knowledge of the desired concept. A "one shot" exposure to a concept will not allow the student to remember the concept for any length of time, and even if he does remember, his limited exposure to the range of conditions under which the concept can be used negates the true meaning of the concept (44). Tightly controlled courses do not allow the individual freedom to explore the concept. Students must be placed in a position where decisions are made and paths of inquiry chosen. Concept formation results when a student evaluates the result of his own decisions (44).

Once the concept is attained, new knowledge may be incorporated into the system with minimal effort. It allows the student to generalize and to make applications and predictions. Testing for concept achievement can best be accomplished by having the student

explain his view of the concept to someone else (44). In the curriculum guide there will be many opportunities for students to report the results of individualized projects.

Knowledge is expanding exponentially and the teacher can no longer dwell on the facts or the isolated discoveries of science. When concept attainment is stressed in teaching, the learner concentrates on the significant and ignores the inconsequential. Concepts flocculate facts.

Conceptual Schemes

Introduction

Pivoting on a fulcrum of concepts, facts and conceptual schemes teeter on an educational see-saw. Both represent extremes in learning. One is tenuous, minute, short-lived, and easily defined while the other is dense, all-encompassing, stable, and elusive to an exacting definition.

Educators decry the value of memorizing facts, and urge that facts be united into concepts. The result is that concepts may accumulate at a rate that they are no more useful than a pile of facts. Concepts must also be united into a hierarchical organization. Such a pattern is called a conceptual scheme.

Defining Conceptual Schemes

Conceptual schemes exist in varying degrees of complexity and magnitude, and represent logical relationships among principles and theories. An exact, universally accepted definition is lacking, but we do know that conceptual schemes relate concepts in an organized manner. To understand a conceptual scheme means that the learner not only knows the individual concepts which comprise the scheme,

but also can describe the relationships which exist among these concepts (44). Conceptual schemes should not be examined as something to be defined, but should be used as a fraternity of ideas.

> These conceptual schemes, models, or theories--call them what you will; call them educated guesses if you like--are the creation of man, not of nature. They represent the pinnacle of explanation in science, and must be classed among the greatest of man's pure intellectual achievements. Such unifying theories are the main goal of science and should be at the focal point of a science curriculum. The kinetic theory of heat, the molecular theory of matter . . . the gene theory of heredity; these are among the 'great ideas' of science--the kind that truly demonstrate the creative aspect of this enterprise (74:300-301).

The Value of Conceptual Schemes

Facts and concepts--the building blocks of conceptual schemes --are constantly challenged by research in the sciences. Because they encompass such broad areas, the change which results from a few small discoveries will not affect a conceptual scheme. Thus, conceptual schemes have survival value.

Although each subject field has its distinctive conceptual schemes, certain schemes are community property: they are found in all the sciences. Because of this factor, conceptual schemes provide a way of relating the various science disciplines.

Finally, the conceputal schemes approach provides the teacher with a roadmap for his lessons without prescribing a specific route. The teacher is free to choose his mode and path of travel by considering student abilities, physical facilities of the school, and his past experiences (44).

Implications for this Study

Several conceptual schemes which seem appropriate for a course in environmental geology were written by the author and approved by his committee. The reviewing panel will be asked to judge the value of these conceptual schemes to a course in environmental geology.

Goals for each unit of study will be stated in terms of concepts and behavioral objectives. The concepts cannot be matched on a one-to-one basis with the conceptual schemes because the latter thread through the entire course and sew unity to the structure, while concepts pertain to a specific topic being discussed. Because concept attainment is enhanced by student performance of certain tasks, the concepts are keyed to certain behavioral objectives in each unit of study.

CHAPTER IV

A CURRICULUM GUIDE

Introduction

Curriculum guides are outlines suggesting course content, include important goals of study, and list a variety of learning experiences (34). Production of such a manual for a course in environmental geology is the intent of this chapter.

Accenting the relationship of man and his physical environment, the topics studied in the course will be those which are typically considered in an introductory physical geology course. Students will be asked to interview city officials, citizens in the community, industrial leaders in the city, and to write to government offices and private industries. The purpose of such activities will be to obtain information concerning mineral production, water use, pollution problems, and teaching aids.

Course Content

Listed below is the Table of Contents from a popular introductory college geology textbook:

Chapter	
1	The Nature & Scope of Physical Geology
2	Matter and Energy
3	The Earth's Place in Space
4	Minerals
5	Igneous Rocks
6	Igneous Activity

Chapter

7	Weathering and Soils
8	Sedimentary Rocks
9	Geologic Time
10	Mass Movement of Surface Material
11	Running Water
12	Underground Water
13	Glaciation
14	Deserts
15	Oceans & Shorelines
16	Deformation of the Earth's Crust
17	Mountains and Mountain-Building
18	Metamorphism & Metamorphic Rocks
19	Earthquakes
20	The Earth's Interior
21	Earth Magnetism & Continental Drift
22	Our Earth's Resources (53).

No stone was left unturned in the search for subject matter in the beginning course, and for a teacher to actually cover all these chapters during one semester would only provide "lip service" to each area. It should be remembered that the purpose of an elementary course is to stimulate the minds of each student, and give direction to the geology major. The stress should not be on the quantity of subject matter covered, but the quality of instruction that is given to whatever is taught. This does not mean that the course has to be a "snap," nor does it imply that it should be an arduous experience in physics, chemistry, and mathematics. Neither will suffice (94).

Thousands of pages of new research data are published each month in the various geoscience journals. Even if a teacher were capable of keeping up with this tremendous amount of information, it does not mean that his first year students can or should. The teacher should stick to the basic principles and teach these principles well. There should be no doubt in a student's mind why any material is being presented. Material should fit a pattern in the

course development, and should not be taught simply because the knowledge is available (20, 58, 63).

Environmental Geology

Every textbook in physical geology does not follow, chapter for chapter, the outline seen in the text cited, although the general sequence for most texts is the same: first, a study of the earth materials, and then a study of the earth processes.

After questioning the rationale for such an approach, it was decided that for this course, the students will begin with a study of the processes of geology, and then focus on the materials of the earth.

Water drinks rock. It has an insatiable thirst, and for eons, water has fallen onto, percolated through, and dripped from the rocks of the earth, dissolving these mineral aggregates. Water streams from the surface and is pumped from the pore spaces of sediments to supply the living elements of the planet with vital fluid. With the exception of an occasional city dweller, whose childhood never afforded him the opportunity to wade in a stream, fish in a river, or fall through the ice on a frozen brook, students come to college with a wide variety of experiences associated with streams, lakes, and along shores. Such a point would be a common denominator on which to base the introduction to the science of geology.

Using the traditional approach, students are exposed to chemical behavior of elements and compounds, crystal systems and endless assortments of "rocks in a box." Such a starting point, with its intimidating vocabulary and complex chemistry, often

discourages students.

Considering the geologic significance of water as a starting point for a course allows the student to study a topic that is familiar to him, permits many student experiments and research projects in the field and classroom, maximizes the use of community resources, and fully integrates the science of geology with man's use of his environment.

Topics in the course will be sequenced as follows:

Environmental Geology → Processes / Materials

Processes	Materials
The Hydrologic Cycle	The Composition of the Crust
Surface Water	Formation of Igneous Rocks
Ground Water	Rock Deformation and Metamorphism
Frozen Water-Glaciers	The Solid Earth
Water in the Sea	
Sedimentation and Sedimentary Rocks	

Members of the reviewing panel were asked to comment on the appropriateness of the five conceptual schemes designed for the course by the author. The reviewer was asked to add conceptual schemes he thought were absent, or delete any schemes he thought were unnecessary. A list of schemes follows:

1. Potential energy is the source of kinetic energy which produces surficial geologic changes.

Gravity is the force which causes streams to flow, ground water to move, glaciers to slide, mass wasting, wind motion, tidal movements in the seas, and turbidity currents. This conceptual scheme considers the importance of gravity as a geologic agent.

2. The rate at which potential energy is converted to kinetic energy governs the rate of geological changes. Man alters this rate of change.

Soil creep and avalanches differ in the rate at which one form of energy is converted into another form of energy. Man affects this rate of change by damming streams to reduce gradients. He is indirectly responsible for salt water intrusion in coastal areas because of the increased ground water gradient caused by excessive well drawdown.

3. Uniformitarianism: a key to interpreting the past.

Popularized by Charles Lyell, the doctrine which stated that the processes which operate on the earth now, also operated on the earth in the geologic past, is a cornerstone to building geologic concepts.

4. Conservation of mass and energy.

Fundamental to the study of the physical sciences is the statement that the sum total of matter and energy is constant when matter and energy interact.

5. Equilibrium occurs among all earth materials--at microscopic and macroscopic dimensions. Man alters this equilibrium.

Chemical reactions and isostatic adjustments are expressions of equilibrium of earth materials.

Structure of the Curriculum Guide

Each unit of study in the curriculum guide is divided into three parts:

1. Section A is an outline of the material to be covered. The exact depth in which the topic is considered is not dictated. Local geological conditions should be an important factor in determining to what extent any unit should be discussed.

2. Section B includes the concepts and related behavioral objectives to be derived from the unit of study.

3. Section C relates the concepts to laboratory activities.

Laboratory oriented courses are time-consuming, and the quantity of subject matter covered is usually limited. Instructors must learn to efficiently use their time when conducting such a program. To facilitate this end, members of the reviewing panel were asked to rate each activity in terms of its efficiency in achieving

its objective. In many cases an objective may be achieved by use of a teacher demonstration or through a lecture. The author is interested in learning which activities should be physically performed by the student and which activities would be more expediently achieved through other means. Panel members marked each activity with one of the following symbols:

ET	efficient use of time
N	neutral
IT	inefficient use of time
IA	inappropriate for the course.

Tallies from the panel members will be recorded after each activity. For example: (3 ET, 1 N, 2 IT). The reader will then be informed that three members of the panel thought the activity was an efficient use of time, one was neutral, and two thought the activity was an inefficient use of time. Any activity that was added to the curriculum guide as the result of a suggestion from a reviewer will not have a parenthetical "score."

Most of the activities are designed to consume only 15 to 20 minutes and can be performed during the class time. The remainder of the period is left for discussion of the topic being investigated. Several related activities might be reserved for a three-hour block of time which the laboratory period affords.

Many of the activities are marked as projects, and are designed to be topics for individual investigation. Students choosing such topics are required to report their findings to the class. Such projects not only allow students to select an area for

intensive study, but allow for a great diversity of material to be studied, and often serve to integrate the science of geology with man's use of his natural resources..

Colleges are fast becoming miniature battlegrounds. Students are no longer content to move hundreds of miles from home and pay high tuition fees just to meekly sit in the corner and listen to the words of the astute professor. They are actively seeking involvement with relevant education and the chance to express their ideas. The project reports provide students with this opportunity and allow the class to profit from the research of other students.

Units of Study

Section A: Unit Outline

I. The Hydrologic Cycle

- A. The Cycle Propellent--Heat Energy
  - 1. The Source of Heat Energy
  - 2. The Effects of Heat Energy
- B. Precipitation
  - 1. Nationally
  - 2. Locally

Section B: Concepts and Related Behavioral Objectives

I. The Hydrologic Cycle

- A. The Cycle Propellent--Heat Energy
  - 1. The Source of Heat Energy
  - 2. The Effects of Heat Energy

Concept

The amount of solar energy received at a point on earth depends on the season of the year, and the latitude of the point.

Behavioral Objective

A student should be able to:

Demonstrate the effect of the sun's seasonal change in zenith distance has on its ability to heat materials.

Concept

At atmospheric pressure, heat energy must be added to or subtracted from a material to bring about a change in the state of matter.

Behavioral Objectives

A student should be able to:

Calculate the amount of heat which must be added to a given quantity of water to cause evaporation under specified conditions.

Calculate the amount of heat which is liberated when a given quantity of water is condensed.

Calculate the amount of heat which must be added to a given quantity of ice to cause melting.

Calculate the amount of heat which is liberated when a given quantity of water is frozen.

B. Precipitation

1. Nationally

2. Locally

Concept

Precipitation patterns can be represented on a two-dimensional map surface by plotting rainfall contours.

Behavioral Objective

A student should be able to:

Construct an isohyetal map when given sufficient data.

Section C: Concepts and Related Laboratory Activities

I. The Hydrologic Cycle

A. The Cycle Propellent--Heat Energy

1. The Source of Heat Energy

2. The Effects of Heat Energy

Concept

The amount of solar energy received at a point on earth depends on the season of the year, and the latitude of the point.

Activity

Fill two shallow containers with a soil sample. Lay one container on the window sill or sidewalk, and prop the other at an angle with the horizontal so that the sun is directly above it. Put a thermometer on the top of each sample and record the temperatures at selected intervals of time. Compare results with students who use a different type of soil, and with students who went outside for measurements as opposed to those who stayed inside. Test the "greenhouse effect" by comparing the heating effect of the sun's rays on a sample of soil placed in a covered aquarium with a sample set in the open. (1 IT, 1 N, 4 ET)

Concept

At atmospheric pressure, heat energy must be added to or subtracted from a material to bring about a change in the state of matter.

Activities

Swab a portion of a student's hand with alcohol, and another portion of his hand with water. Discuss the difference in behavior of the two liquids. (2 N, 4 ET)

Determine the dew point by adding ice to a beaker of water at room temperature, and observe the temperature at which condensation occurs. Use metal cups, glass beakers, styrofoam containers. Comment on any difference in data collected. (1 N, 5 ET)

Discover the heat of fusion of ice by heating a beaker of ice water, and plotting a graph of temperature versus time of heating. (6 ET)

Project

Sublimation may be demonstrated by having a student heat a beaker containing iodine crystals. Place some ice in a watch glass, and cover the beaker with the watch glass. Do not allow the crystals to melt, and perform this exercise in a chemical fume hood. (3 N, 3 ET)

References

B-9: Heat of Condensation, pp. 409-410.
B-10: Dew Point, pp. 55-56.

B. Precipitation

1. Nationally

2. Locally

Concept

Precipitation patterns can be represented on a two dimensional map surface by plotting rainfall contours.

Activities

Plot isohyets on a map of the United States. Data should be provided for at least one city in each state. (1 IT, 1 N, 4 ET)

Repeat the above activity using a map of the state where the college is located. Provide data for cities throughout the state. (1 IT, 2 N, 3 ET)

Section A: Unit Outline

II. Surface Water

A. Local Streams

1. Topographic Maps

2. Local Watersheds

B. Energy, Friction, and Stream Flow

1. Gravity: Driving Force of Streams

2. Friction: Expending Energy

3. Gauging Stream Flow

C. Geologic Work of Streams

1. Stream Load

2. Abrasion

3. Changes of Stream Channels with Time

4. Stream Deposition

Section B: Concepts and Related Behavioral Objectives

II. Surface Water

A. Local Streams

1. Topographic Maps

2. Local Watersheds

Concept

Topographic maps are three-dimensional portraits from which a trained observer can derive significant geological information.

Behavioral Objectives

A student should be able to:

Construct a topographic map by plotting contours when data is plotted.

Construct a topographic profile of an area.

Identify various stream patterns from photographs or a topographic map.

Compute the area of a watershed using a topographic map, tracing paper, and a beam balance.

B. Energy, Friction, and Stream Flow

1. Gravity: Driving Force of Streams

2. Friction: Expending Energy

3. Gauging Stream Flow

Concept

Gravity is the force responsible for the flow of streams and the consequent degradation caused by the movement of water.

Behavioral Objectives

A student should be able to:

Determine the gradient of a stream using a topographic map.

Construct a longitudinal profile of a stream.

List and explain the factors which influence a stream's ability to carry solid and dissolved particles.

Contrast the formation of alluvial fans and deltas in terms of the type of sediment, stream source, and depositional stratification.

Concept

Man creates flood conditions by paving large areas with impervious materials which reduce infiltration and increase runoff.

Behavorial Objectives

A student should be able to:

Construct a graph to relate water quantity to surface area when rainfall is constant.

Construct a graph to relate water quantity to rainfall when the area is constant.

Estimate the time of a river's flooding crest when given sufficient data and graphs.

C. Geologic Work of Streams

1. Stream Load
2. Abrasion
3. Changes of Stream Channels with Time
4. Stream Deposition

Concept

Streams alter their cross-sectional and longitudinal profiles in response to available energy.

Behavioral Objectives

A student should be able to:

Mathematically explain the relationship between stream velocity and competence.

Describe how the competence, capacity, gradient, velocity, and valley form of a stream changes with time.

Make a cross-sectional diagram of a stream. Label natural levees, flood plain, Yazoo stream, and explain how each is formed.

Use a diagram to explain what is meant by the profile of equilibrium of a stream.

Use a diagram to explain why the wetted perimeter of a stream is an important parameter in governing stream flow.

Section C: Concepts and Related Laboratory Activities

II. Surface Water

A. Local Streams

1. Topographic Maps

2. Local Watersheds

Concept

Topographic maps are three dimensional portraits from which a trained observer can derive significant geological information.

Activities

Study the mechanics of map reading by examining maps which offer a variety of geologic settings. Note such things as map scale, quadrangle area, latitude and longitude, range and townships, contour interval, and map symbols. (1 N, 5 ET)

Make a contour map by plotting contour lines between the elevation points that are recorded on a sheet distributed by the teacher. (1 N, 5 ET)

Select an appropriate distance on a topographic map and construct a topographic profile of the area. (1 N, 5 ET)

Discover the "rule of the V's" by making a model of a stream valley and stream terrace with index cards. Cut one card on a diagonal, and tape the long legs of the resultant triangles together. When held so that the hypotenuse of the triangles is level, this represents the stream valley. Tape the other cards to the hypotenuse of each triangle. These represent the stream terrace. Draw a "contour line" across the terrace and show what path the line should follow as it descends into the valley and up to the other side of the stream valley. (2 IT, 2 N, 2 ET)

On topographic maps of the area where the college is located, trace the divide for the watershed of a stream and compute its area. This can be done by weighing the paper on

which the watershed was traced, and comparing its weight to a piece of paper (of the same stock) whose "map area" is known. Make a histogram depicting monthly rainfall, and another histogram representing the monthly volume of rain the watershed received. (3 N, 3 ET)

References

B-6: Contours and Contour Maps, pp. 79-82.
B-6: Description of Landforsm by Use of Topographic Profiles, pp. 117-122.
B-10: Map Exercises, pp. 1-8.
B-16: Topographic Maps, pp. 17-28.

B. Energy, Friction, and Stream Flow

1. Gravity: Driving Force of Streams

2. Friction: Expending Energy

3. Gauging Stream Flow

Concept

Gravity is the force responsible for the flow of streams and the consequent degradation caused by the movement of water.

Activities

Calculate the gradients of several streams on a topographic map. Use map distances and elevation differences between two points. (2 N, 4 ET)

Construct longitudinal profiles of various streams in at least two different geological settings. What is the general shape of the profile? What effect does an artificial base level have on the profile? (2 N, 4 ET)

Concept

Man creates flood conditions by paving large areas with impervious materials which reduce infiltration and increase runoff.

Activities

Construct a graph which relates water quantity to surface area when rainfall is constant. (1 IT, 5 N)

Construct a graph which relates water quantity to rainfall when the area is constant. (1 IT, 3 N, 2 ET)

Projects

Visit the city agency responsible for flood control. Obtain the history of flooding in the area and information concerning preventative and emergency controls used by this agency to protect the city from flooding. (2 N, 4 ET)

Investigate the effect that man has on potential runoff. Measure the area of a parking lot in a shopping plaza. How much rainfall does the city receive each month? Determine the amount of runoff from the parking lot each month, and for a unit of rain (one inch, two inches, etc.). Set up charts in the various stores of the plaza to inform citizens of these facts. (2 N, 4 ET)

C. Geologic Work of Streams

1. Stream Load

2. Abrasion

3. Changes of Stream Channels with Time

4. Stream Deposition

Concept

Streams alter their cross-sectional and longitudinal profiles in response to available energy.

Activity

Visit a construction site on campus. Spray one of the mounds of dirt with a water hose, and vary the intensity of the spray. Observe the erosion and deposition which results on a variety of slopes. Slice into an alluvial fan and note whether stratification is present. (2 N, 4 ET)

Projects

Write to the U. S. Army Engineering Stream Research Stations in Vicksburg and Jackson, Mississippi. Obtain information concerning the history, purpose, and the research being conducted at these laboratories. (1 IT, 3 N, 2 ET)

Make a photographic record of the erosion and mass wasting which occur on a mound of dirt at a construction site on campus. Use a shovel to make "cliffs" in the dirt, undercut other "cliffs." Take photographs over a series of days when rain is forecast. (1 IT, 2 N, 3 ET)

References

B-1: Stream Erosion and Channel Form, pp. 88-92.
B-1: Denudation and Drainage Changes, pp. 93-95.
B-1: Sedimentation I & II, pp. 100-109.
B-6: Development of Stream Valleys and Stream-eroded Landscapes, pp. 123-130.
B-12: Streams, pp. 83-99.
B-12: Landscape Development, pp. 101-112.

Section A: Unit Outline

III. Ground Water

A. Water Income and Expense

1. Factors Affecting Infiltration

2. Evapotranspiration

B. Vertical Distribution of Water

1. Soil Water Belt

2. Zone of Aeration

3. Zone of Saturation

C. Geologic Work of Ground Water

1. Ground Water and Carbonate Rocks

2. The Karst Geomorphic Cycle

D. Man's Use of Ground Water

1. Economic Aspects

2. Legal Aspects

Section B: Concepts and Related Behavioral Objectives

III. Ground Water

A. Water Income and Expense

1. Factors Affecting Infiltration

2. Evapotranspiration

Concept

The water available for infiltration depends on the type of soil, intensity and amount of precipitation, runoff, vegetative cover, topography, and land management.

Behavioral Objectives

A student should be able to:

List four factors which affect the infiltration of water into the soil. Explain the importance of each by citing examples.

Explain the procedure used to experimentally determine the amount of water transpired by a plant.

Construct a water budget graph for a given area.

B. Vertical Distribution of Water

1. Soil Water Belt

2. Zone of Aeration

3. Zone of Saturation

Concept

Pore spaces in rock and soil allow fluids to accumulate, and if these spaces are interconnected, the influence of gravity will cause the fluid to flow.

Behavioral Objectives

A student should be able to:

Diagram a microscopic view of a rock which has a high porosity and a high permeability, and another rock which has a high porosity but low permeability.

Explain the procedures and limitations that are involved in the experimental determination of porosity, permeability, and water retention properties of a material.

Use a diagram to explain what is meant by the Soil Water Belt, Zone of Aeration, and Zone of Saturation. Explain the difference between these zones.

Explain the relationship between particle size and capillary action.

Use a neatly constructed labelled diagram to show the conditions which give rise to an artesian well system.

Use a neatly constructed labelled diagram to show the cause of influent and effluent streams.

Concept

Mass wasting processes are enhanced by the presence of water in the soil. These processes often sculpture the landscape at great economic expense to man.

Behavioral Objective

A student should be able to:

Contrast the conditions which give rise to soil creep, slumping, and sheet wash.

C. Geologic Work of Ground Water

1. Ground Water and Carbonate Rocks

2. The Karst Geomorphic Cycle

Concept

Ground water dissolves great quantities of rock, causing degradation of the earth's crust and imposing significant economic consequences to man.

Behavioral Objectives

A student should be able to:

Draw a graph which shows the relationship between temperature and the solution of carbon dioxide in water.

Draw a graph which shows the relationship between pressure and the solution of carbon dioxide in water.

Explain how temperature and pressure changes affect the solution of limestone by carbonic acid.

Explain why a cloudy suspension of limewater clears when more carbon dioxide is added to the mixture.

Identify karst areas on a topographic map and explain the cause of such features as sinks, water-filled sinks, disappearing streams.

Contrast the properties of temporary and permanently hard water as to cause, effects on soap sudsing, and water softening treatment.

Use a diagram to explain how water softeners operate and are recharged. Comment on the use of borax, zeolites, synthetic resins, and table salt in water softeners.

D. Man's Use of Ground Water

1. Economic Aspects

2. Legal Aspects

Concept

Man's use of ground water has caused salt water intrusion, earth subsidence, and water pollution. Such action has stimulated an intensive search for new water sources and prompted legal action which prohibits indiscriminate use of this natural resource.

Behavioral Objectives

A student should be able to:

Use a neatly constructed and labelled diagram to show the conditions which give rise to salt water intrusion.

Use a neatly constructed and labelled diagram to show the conditions which cause the lowering of the water table due to excessive well drawdown.

Illustrate the relationship which exists at a fresh water-salt water interface. A diagram and accompanying mathematics should explain why there is 40 feet of fresh water below the sea level surface on land for every foot the water table is above sea level.

Discuss measures taken by city officials to insure that surface and ground water supplies are free from pathogenic agents.

Discuss the legal restrictions which govern the use of ground and surface water supplies by individuals and industries.

Section C: Concepts and Related Laboratory Activities

III. Ground Water

A. Water Income and Expense

1. Factors Affecting Infiltration

2. Evapotranspiration

Concept

The water available for infiltration depends on the type of soil, intensity and amount of precipitation, runoff, vegetative cover, topography, and land management.

Activities

Experimentally determine the amount of water a plant transpires, by having a student cover several species of plants with plastic bags for a day. Compare the weight of the bag before and after the experiment. (1 IT, 2 N, 3 ET)

Examine stomata cells of various plant species. Prepare some microscope slides, and also examine prepared slides from the biology department. (1 IA, 4 N, 1 ET)

Integrate the factors of precipitation, potential evapotranspiration, and soil water budget by making a graph of these factors for various cities in the United States. (4 N, 2 ET)

Repeat the activity above by graphing a water budget for various cities in the state where the college is located. (2 IT, 4 N)

Project

Conduct individual research on the topic of transpiration. Select a small plot on campus, and estimate how much transpiration occurs there each day. (1 IT, 4 N, 1 ET)

References

B-1: Water Budget, pp. 66-70.
B-2: Water Budget, pp. 266-274.

B. Vertical Distribution of Water

1. Soil Water Belt

2. Zone of Aeration

3. Zone of Saturation

Concept

Pore spaces in rock and soil allow fluids to accumulate, and if these spaces are interconnected, the influence of gravity will cause the fluid to flow.

Activities

Investigate the influence of particle size on porosity, permeability, and water retention properties of various materials.

Fill a large graduated cylinder with glass beads. Another graduated cylinder is filled with water to a recorded level. This water is added to the cylinder containing the beads so that all the beads are covered. Compute the porosity and graph the percent porosity versus grain size. Save the cylinder of water and beads for an experiment dealing with permeability and water retention. (6 ET)

Repeat the above procedure for two other sizes of beads. (6 ET)

Repeat the above activity using three uniform sizes of sand grains. (6 ET)

Repeat the above activity using a mixture of bead sizes. (6 ET)

Repeat the above activity using mixtures of sand grain sizes. (6 ET)

Use the cylinders of beads and water or sand and water obtained from the experiment above, and determine permeability of the samples. Cover the cylinder with a permeable membrane. Turn the cylinder upside down and determine the time it takes the water to drain. Graph particle size versus flow rate of the water. How much water was collected? (6 ET)

Using the data from the experiment above, make a graph which relates grain size to the water retention properties of the material. (6 ET)

Investigate the relationship between water retention of particles and the surface area of these particles. Count the number of beads used in the previous experiment, and

compute the total surface area of the beads. Make a graph which relates surface area to the water retained for each of the three sizes of beads. (1 IT, 3 N, 2 ET)

Experimentally determine the relationship between particle size and capillarity. Fill a plastic column with sand and another with silt. Cover the bottom of each tube with a permeable membrane, and place in a dish of water. Note the height of the water's rise in each tube. (6 ET)

Compare the capillary action of various fluids when the type of material is held constant. Note the height and time it takes such fluids as water, alcohol, glycerin, and syrup to rise on strips of blotting paper. (2 IT, 3 N, 1 ET)

Microscopically examine xylem and phloem tubes of various plant species. Relate this to the stomata cell activity and the transpiration of plants. (1 IA, 5 N)

Experimentally determine the water content of various soil samples. A construction site will allow samples to be collected at depth. Weigh the sample, heat, and reweigh. (3 N, 3 ET)

Construct a soda straw well using a clean sand aquifer, a beaker, cotton, a pin, and a straw. Put the sand in the beaker and add water. What problems are encountered when the student inserts his straw in the sand and attempts to draw water? Have students put pin holes through the bottom of the straw, and fill with cotton. Does the presence of the cotton filter solve the problem of drawing up sand? (1 IT, 2 N, 3 ET)

Demonstrate capillarity by putting a rubber band around two glass plates. Separate the plates at one corner with a wedge of paper, and insert the plates into a dish of water. Where does the water rise the highest? Why? (1 N, 5 ET)

Demonstrate the adhesive force of water by wetting the surface of two glass plates, and pressing them together. Can the plates be easily separated? (1 IT, 2 N, 3 ET)

Demonstrate the effect of capillary action on soils in arid regions. Place a mixture of salt and soil in a container. Cover with a layer of soil, and wet. Set in the sun or under a sunlamp to dry. Does capillary action bring the salt to the surface of the soil? (6 ET)

Projects

Construct a model of an influent and effluent stream on a stream table, and explain the conditions necessary for the formation of each type of stream. (2 IT, 4 N)

Using a stream table, set up a variety of working springs. (1 IT, 2 N, 3 ET)

Using a large aquarium, construct a working model of an artesian well system. (2 N, 4 ET)

Construct a working model of a geyser. Show the relationship between boiling point and pressure. Provide information of geyser activity in Yellowstone Park and Iceland. (1 IT, 2 N, 3 ET)

In May, 1970, Dr. Z. V. Haralik presented a paper to the Virginia Academy of Science in which he claimed that water dowsing has a scientific basis. Obtain a copy of this paper, and report to the class. (1 N, 5 ET)

Visit a commercial well digger and obtain information concerning aquifers in the region. Ask for data concerning well depth and well positions in the area, and plot these well positions on a topographic map. (3 N, 3 ET)

C. Geologic Work of Ground Water

1. Ground Water and Carbonate Rocks

2. The Karst Geomorphic Cycle.

Concept

Ground water dissolves great quantities of rock, causing degradation of the earth's crust and imposing significant economic consequence to man.

Activities

Determine the acidity of fresh rain water, tap water, distilled water, three carbonated beverages, by using a pH meter and pH paper. (1 N, 5 ET)

Determine if the addition of carbon dioxide to water changes its pH, by exhaling through a straw into ice water. Record pH readings as determined by a pH meter or pH paper. Make three samples for use in the following experiments. (6 ET)

Repeat the above activity and determine the pH by colorimetry methods (2 IT, 3 N, 1 ET)

While gently heating one of the samples of acidic water obtained in the above activity, record temperature and pH readings. Use a pH meter. Graph the results. (1 IT, 1 N, 4 ET)

Cause calcium carbonate to precipitate by exhaling through a straw into a beaker of cold limewater. Prepare three samples. When the solution of limewater becomes cloudy, add one of the samples of acidic water produced in the activity above. Add club soda to another beaker containing the cloudy suspension. Continue to exhale into the third limewater solution for a prolonged period of time. Is there any change in the latter sample? Use a pH meter to record data before and after the acidic solutions are added. (3 IT, 3 ET)

Examine the following topographic maps which illustrate karst topography: Mammoth Cave, Kentucky; Crystal Lake, Florida; Cobleskill, New York; Carlsbad, New Mexico. (1 N, 5 ET)

Project

Put some limestone or marble chips into a bottle of club soda. Reseal the bottle and keep in the refrigerator. Let one bottle set undisturbed, and agitate the other bottle once a day. Observe for several weeks. (1 IA, 1 IT, 2 N, 2 ET)

References

B-1: Ground Water, pp. 71-74.
B-4: Determining the Dissolved Oxygen Content in water, 56-67.
B-5: Karst Topography Map, pp. 89-90.
B-10: Soils and Carbonates, pp. 35-40.
B-12: Ground Water, pp. 113-122.
B-16: Karst Topography Maps, p. 36.

D. Man's Use of Ground Water

1. Economic Aspects

2. Legal Aspects

Concept

Man's use of ground water has caused salt water intrusion, earth subsidence, and water pollution. Such action has stimulated an intensive search for new water sources and prompted legal action which prohibits indiscriminate use of this natural resource.

Activities

Obtain water samples from various places: tap water, stream water, pond water, lake water, well water. Determine the amount of dissolved solids in the water by boiling the water. Use a dissolved solids meter for comparison of results. (6 ET)

Determine the effects water softeners have on hard water. Determine the amount of dissolved solids in several water samples, and then allow this water to pass through a water softener. Compare the dissolved solids of the treated water with the untreated water. (1 IT, 3 N, 2 ET)

Repeat the above activity by using hard water produced by dissolving calcium carbonate in distilled water. (3 IT, 1 N, 2 ET)

Mine waters or industrial waters containing sulfuric acid are often dumped on carbonate rocks to reduce their pH. Record the pH of dilute sulfuric acid, and then pour it on carbonate rocks, and then record the pH. What "new product" is formed? (1 N, 5 ET)

Examine the effects of hard water on the sudsing ability of soaps. Add a drop of liquid soap to several water samples, and shake. Add a water softener to another series of water samples, and then add a drop of liquid soap. Shake. Compare the treated and untreated water samples. (1 IA, 1 IT, 4 ET)

Projects

Using a stream table or an aquarium, construct a working model which illustrates salt water intrusion. Establish a "lake" of salt water, and then sink a soda straw well nearby to extract fresh water from the aquifer. Is it possible to detect salt water intrusion as the fresh water is pumped from the well? (3 N, 3 ET)

Determine the density of various wooden blocks and float them in a large container. Study and explain all factors regarding the physics of flotation. Then, using a U-tube arrangement, illustrate the density balance which occurs at a fresh water-salt water interface. (2 IT, 2 N, 2 ET)

Experience the effects of excessive well discharge on the water table surface. Fill a large container with a fine grained aquifer, and establish a high water table. Sink two soda straw wells about six inches apart. While one student withdraws a large quantity of water from his well, another student tests the well production from his well which penetrates only a short distance below the water table. Why should fine grained material be used instead of coarse grained material? (6 ET)

Conduct research on the topic of water softeners. Report on commercial water softeners, zeolites, synthetic resins, and the economic considerations of hard water. Interview people who use well water in the area, city water board officials. (1 IT, 1 N, 4 ET)

Visit the City Health Board and obtain information concerning the pathological conditions of the local water, water treatment facilities and procedures, sewage treatment procedures, septic tank requirements. (1 IA, 5 ET)

Dissolved solids are removed from water by deionizing processes. Write to Mr. A. W. Michalson, Illinois Water Treatment Company, 840 Cedar Street, Rockford, Illinois, 61105. Ask for information and brochures concerning the Illco-way Double Deionizer. (5 N, 1 ET)

Interview the management of several local industries. How much water do they use? What are their water costs? What is done with waste water? (4 N, 2 ET)

Visit a lawyer to discuss the controversial question as to who owns water. What can and what is a person prohibited from doing with the water in a stream on his property and the ground water under his property? (1 IT, 2 N, 3 ET)

Section A: Course Outline

IV. Frozen Water - Glaciers

A. Glacial Birth

1. Formation

2. Movement

B. Classification of Glaciers

1. Valley Glaciers

2. Continental Glaciers

C. Theories of Continental Glacial Origin

1. Solar-Topographic Hypothesis

2. Earth Orbital Variations

3. Hypothesis of Atmospheric Changes

4. Hypothesis of Changes in Oceanic Circulation

D. Pleistocene Glaciation

1. Glacial Cycles

2. Isostatic Adjustments

Section B: Concepts and Related Behavioral Objectives

IV. Frozen Water - Glaciers

A. Clacial Birth

1. Formation

2. Movement

Concept

Stress produced by gravitational forces causes melting and plastic behavior of ice, thus initiating the flow of glaciers.

Behavioral Objective

A student should be able to:

Cite experiments which demonstrate the difference between regelation and the plastic behavior of ice.

B. Classification of Glaciers

1. Valley of Glaciers

2. Continental Glaciers

C. Theories of Continental Glacial Origin

1. Solar-Topographic Hypothesis

2. Earth Orbital Variations

3. Hypothesis of Atmospheric Changes

4. Hypothesis of Changes in Oceanic Circulation

Concept

Although glacial erosion and deposition are not altering the inhabited areas of the world today, there were times in the past when glaciers greatly affected the landscape.

Behavioral Objectives

A student should be able to:

List five erosional landforms caused by valley glaciation, and identify them on a topographic map.

List five landforms caused by continental glaciation, and identify them on a topographic map.

Describe what is meant by a varve deposit, and explain how such sedimentary deposits originate.

Explain at least one theory concerning the cause of glacial periods.

D. Pleistocene Glaciation

1. Glacial Cycles

2. Isostatic Adjustments

Concept

Even though they were not covered with glacial ice, sea coast areas around the world were affected by eustatic changes in sea level caused by glaciation.

Behavioral Objective

A student should be able to:

Using a topographic map, identify former shorelines due to a higher stand of sea level.

Concept

Accumulation of large masses on the surface of the earth cause the crust to respond isostatically.

Behavioral Objective

A student should be able to:

Explain the mechanics of isostasy.

Section C: Concepts and Related Laboratory Activities

IV. Frozen Water - Glaciers

A. Glacial Birth

1. Formation

2. Movement

Concept

Stress produced by gravitational forces causes melting and plastic behavior of ice, thus initiating the flow of glaciers.

Activities

Support an ice cube on an elevated platform such as a ringstand. A loop of wire with a weight attached is placed over the ice cube. Set outside on a cold day, or in the refrigerator. Use a variety of weights and gauges of wire. (2 N, 4 ET)

Examine the effects of prolonged stress on ice by cutting a 24 x 3 x 1 inch strip from a block of ice. Put the ice between two strong boxes, and loop a string with a heavy weight attached over the ice. Let the string rest on a piece of wood or cardboard to prevent regelation at the string-ice contact. Make a photographic record of the deformation. (6 ET)

B. Classification of Glaciers

1. Valley of Glaciers

2. Continental Glaciers

C. Theories of Continental Glacial Origin

1. Solar-Topographic Hypothesis

2. Earth Orbital Variations

3. Hypothesis of Atmospheric Changes

4. Hypothesis of Changes in Oceanic Circulation

Concept

Although glacial erosion and deposition are not altering the inhabited areas of the world today, there were times in the past when glaciers greatly affected the landscape.

Activity

Examine the following topograhpic maps which illustrate the erosional and depositional effects of alpine glaciation: Chief Mountain, Montana; Mt. Rainier, Washington; Holden, Washington; Yosemite, California; Cordova, Alaska. For maps of continentally glaciated areas, see: Whitewater, Wisconsin; Effingham, Illinois; Sun Prairie, Wisconsin; Kingston, Rhode Island. (6 ET)

References

B-1: Mountain Glaciation, pp. 96-99.
B-5: Glacial, pp. 103-110.
B-6: Glaciers, pp. 131-142.
B-12: Influences of Glacial Processes, pp. 135-148.
B-16: Maps of Glacial Areas, pp. 43-44.

D. Pleistocene Glaciation

1. Glacial Cycles

2. Isostatic Adjustments

Concept

Even though they were not covered with glacial ice, some sea coast areas around the world were affected by eustatic changes in sea level caused by glaciation.

Activity

On a topographic map, identify evidence which indicates a higher stand of sea level.

Concept

Accumulation of large masses on the surface of the earth causes the crust to respond isostatically.

Activity

Review the physics of flotation. Choose a wood sample and float various masses in water. Then use a variety of woods, and float a standard mass of these woods in water. (1 IT, 3 N, 2 ET)

Section A: Unit Outline

V. Water in the Sea

A. Description of Waves

1. Physical Properties

2. Factors Affecting Wave Size

B. Wave Behavior

1. Changes of Waves Near Shore

2. Distribution of Wave Energy

C. Waves Attack the Shore

1. Erosion

2. Deposition by Longshore Drift

3. Profile of the Shore

4. Profile of Equilibrium

D. Artificial Interference of Waves

1. Structures Perpendicular to Shore

2. Structures Parallel to Shore

E. Wind Action

1. Physical Considerations

2. Effects of Wind Erosion

Section B: Concepts and Related Behavioral Objectives

V. Water in the Sea

A. Description of Waves

1. Physical Properties

2. Factors Affecting Wave Size

Concept

Wind and gravitational energy are converted to wave energy which is then translated to mechanical energy as the waves break against the shore.

Behavior Objectives

A student should be able to:

Mathematically describe the relationship between wave length, period, and velocity.

List three factors which affect wave size, and explain the significance of each.

B. Wave Behavior

1. Changes of Waves Near Shore

2. Distribution of Wave Energy

C. Waves Attack the Shore

1. Erosion

2. Deposition by Longshore Drift

3. Profile of the Shore

4. Profile of Equilibrium

Concept

Wave behavior is dependent on the depth of the water.

Behavioral Objectives

A student should be able to:

Describe the changes in waves as they near the shore, and the effects these changes have on the erosional capacity of the waves.

Use a diagram to illustrate the differences in the energy distribution of waves as they strike against headlands and into bays.

Explain the cause of longshore drift, and use a diagram to illustrate how this water movement causes bay barriers, spits, and tombolos.

Concept

Whereas summer waves build up the coast, winter waves are larger and cause great erosion of the coasts.

Behavioral Objectives

A student should be able to:

Using a neatly constructed and labelled diagram, illustrate the features of the shore profile, and show how this would change from summer to winter.

Use a diagram to explain what is meant by the profile of equilibrium as this term is used to describe beaches.

D. Artificial Interference of Waves

1. Structures Perpendicular to Shore

2. Structures Parallel to Shore

Concept

Man's interference with the shape of the shoreline often produces unwanted erosion and deposition.

Behavioral Objective

A student should be able to:

Use a diagram to explain how man-made structures such as jetties and breakwaters interfere with the normal behavior of waves.

E. Wind Action

1. Physical Considerations

2. Effects of Wind Erosion

Concept

Wind action greatly alters the landscape in areas covered with unconsolidated material and sparce vegetation.

Behavioral Objectives

A student should be able to:

Sketch a graph which relates wind velocity to the size of sediment transported.

Identify seif, transverse,and barchan sand dunes on a topographic map.

List several factors which contributed to the creation of the "dust bowl" region of Oklahoma, and explain why this region of the country is no longer experiencing the severe physical and economic damage which results from wind erosion.

Section C: Concepts and Related Laboratory Activities

V. Water in the Sea

A. Description of Waves

1. Physical Properties

2. Factors Affecting Wave Size

Concept

Wind and gravitation energy is converted to wave energy which is then translated to mechanical energy as the water wave breaks against the shore.

Activity

Investigate all parameters of wave behavior by using a ripple tank. (1 IT, 5 ET)

B. Wave Behavior

1. Changes of Waves Near Shore

2. Distribution of Wave Energy

C. Waves Attack the Shore

1. Erosion

2. Deposition by Longshore Drift

3. Profile of the Shore

4. Profile of Equilibrium

Concept

Wave behavior is dependent on the depth of the water.

Activities

Use glass plates to vary water depth in ripple tank and experimentally observe wave behavior. (1 IT, 1 N, 4 ET)

Examine shoreline features on the following topographic maps: Oceanside, California; Point Reyes, California; Toms River, New Jersey; Emerado, North Dakota; Barea, Ohio; Barngate, New Jersey. (6 ET)

Illustrate the effect of oil pollution to beaches. Construct a sand beach area in a ripple tank, and pour a small amount of motor oil on the water. Start the wave generator, and allow a fan to blow the oil slick toward the beach area. Suggest and try various methods of cleaning the oil from the sand. (2 N, 4 ET)

References

B-5: Shoreline Features, pp. 113-118.
B-6: Shoreline Features, pp. 143-145.
B-7: Ripple tanks, pp. 169-175.
B-9: Ripple tanks, pp. 460-472.
B-12: Oceans, Lakes, and Shoreline Features, pp. 149-164.
B-16: Shoreline Development, pp. 46-47.

D. Artificial Interference of Waves

1. Structures Perpendicular to Shores

2. Structures Parallel to Shores

Concept

Man's interference with the shape of the shoreline often produces unwanted erosion and deposition.

Activity

Place barriers parallel to, and perpendicular to, the edge of a ripple tank, and observe waves and the behavior of waves as they strike these barriers.

Project

Who owns beaches? Write Miami, Florida, Mayor Jay Dermer, and obtain information concerning his fight to make all the resort hotels open their beaches to the public. Ask about the 1953 decision by Circuit Judge Charles Carroll in which the court declared that the public has the right of access to any portion of the

beach. Write to several hotels on Miami Beach and obtain information concerning their side of this debate. (2 N, 4 ET)

E. Wind Action

1. Physical Considerations

2. Effects of Wind Erosion

Concept

Wind action greatly alters the landscape in areas covered with unconsolidated material and sparce vegetation.

Activity

Examine the following topographic maps which illustrate the effect of wind erosion: Asby, Nebraska; Provincetown, Massachusetts; Hartford, Michigan.

Project

Make a wind tunnel using clear plastic pipe. Make a funnel so that the wind generated from a small room fan can be introduced into the four to six inch pipe. Drill holes in the top of the tunnel so that sand grains may be dropped into the wind. These small holes may be plugged with cotton or taped over when not in use.

The water to land ratio in Oklahoma is one of the highest of any state in the country. Write to the Department of the Interior of the State of Oklahoma, and obtain information concerning their program which brought an end to the "dust bowl" conditions in that state.

References

B-12: Wind, pp. 123-133.
B-13: Work of the Wind on the Land, pp. 248-256.
B-16: Topographic Maps of Wind Sculptured Lands, p. 36.

Section A: Unit Outline

VI. Sedimentation and Sedimentary Rocks

A. Solids Deposited in Water

1. Factors Controlling Settling of Particles

2. Interpreting Types of Stratification

B. Features of Sedimentary Rocks

1. Lithification

2. Characteristics Due to Transportation

3. Characteristics Due to Other Factors

C. Stratigraphy

1. Basic Laws

2. Stratigraphic Columns

3. Breaks in the Rock Record

D. Sedimentary Rocks

1. Clastic

2. Non-clastic

3. Mineral Composition of Sedimentary Rocks

Section B: Concepts and Related Behavioral Objectives

VI. Sedimentation and Sedimentary Rocks

A. Solids Deposited in Water

1. Factors Controlling Settling of Particles

2. Interpreting Types of Stratification

Concept

Particle size is the controlling factor in determining the settling rate of a material when it is deposited in still water.

Behavioral Objective

A student should be able to:

Use the Wentworth Scale and Stokes Law to explain how the size of a particle influences its rate of settling.

B. Features of Sedimentary Rocks

1. Lithification

2. Characteristics Due to Transportation

3. Characteristics Due to Other Factors

Concepts

Stratification is the most distinguishing feature of sedimentary deposits, and when combined with secondary features such as mud cracks and ripple marks, reflects the conditions under which the material was deposited.

Behavioral Objectives

A student should be able to:

Explain the difference in the conditions which are responsible for forming parallel and cross-stratification of sedimentary beds.

Use a neatly constructed and labelled diagram which shows the difference between a well sorted, well cemented sandstone, and a poorly sorted, well cemented sandstone.

Explain how the following characteristics of sedimentary rocks are formed: rounding, sorting, imbrication, and ripple marks.

C. Stratigraphy

1. Basic Laws

2. Stratigraphic Columns

3. Breaks in the Rock Record

Concept

Sedimentary rocks are usually deposited on a horizontal surface with the oldest rocks being on the bottom of an exposure.

Behavioral Objectives

A student should be able to:

Explain what is meant by, and the importance of each, of these statements: Law of Superposition; Law of Original Horizontality; Law of Faunal Succession.

Construct a stratigraphic column when given sufficient data.

Use a neatly constructed and labelled diagram to explain the difference between a nonconformity, an unconformity, an angular unconformity, and a disconformity.

D. Sedimentary Rocks

1. Clastic

2. Non-Clastic

3. Mineral Composition of Sedimentary Rocks

Concept

Sedimentary rocks can be classified according to the nature of the particles or the manner in which the particles were formed.

Behavioral Objectives

A student should be able to:

Identify the following rock samples: sandstone; shale; limestone; breccia; arkose; conglomerate; and propose two systems which could be used to classify these rocks.

Use a diagram to illustrate the difference between a conglomerate and a breccia, and explain the significance of each type of deposit.

Explain the importance of arkose in determining the geologic history of sedimentation.

Section C: Concepts and Related Laboratory Activities

VI. Sedimentation and Sedimentary Rocks

A. Solids Deposited in Water

1. Factors Controlling Settling of Particles

2. Results of Settling

3. Types of Stratification

4. Arrangement of Particles Within a Stratum

Concept

Particle size is the controlling factor in determining the settling rate of a material when it is deposited in still water.

Activities

Discover the effect of ionic solutions on colloidal sized particles. Add water to a flask containing fine soil, and shake. Filter the suspension, and pour the clear liquid into several test tubes. Add a salt to each test tube. Use sodium chloride, calcium chloride, aluminum sulfate, sugar, and copper sulfate. (3 N, 3 ET)

Flocculation may be demonstrated by adding ink and alum to a filtered suspension of fine soil and water. Add ammonium hydroxide, and observe. (4 N, 2 ET)

Illustrate how graded bedding is formed by putting gravel in a large transparent container. Add water, shake the container, and observe the manner in which the particles settle. (6 ET)

Project

Using a set of sieves, prepare size samples of sediment according to the Wentworth Scale. Display these samples and use for reference.

References

B-1: Sedimentation, pp. 100-109.
B-7: Stokes Law, pp. 333-334.
B-13: Stokes Law, pp. 281-288.

B. Features of Sedimentary Rocks

1. Lithification

2. Characteristics Due to Transportation

3. Characteristics Due to Other Factors

Concepts

Stratification is the most distinguishing feature of sedimentary deposits, and when combined with secondary features such as mud cracks and ripple marks, reflects the conditions under which the material was deposited.

Activities

Produce ferruginous cement by adding fine iron powder to some well sorted sand or silt. Add water and allow the test tube to set for a few days. Examine the mixture under a binocular microscope. (6 ET)

Examine thin sections of sedimentary rocks, noting pore space, cement, and other characteristics. (1 N, 5 ET)

Examine the effects of rock abrasion by adding some broken pieces of brick to a can of water. Put the cover on, and shake. Periodically examine the brick pieces for roundness. (3 N, 3 ET)

Demonstrate mudcrack formation. Soak clay in water overnight. Take a large, flat container and spread the clay to dry. Vary clay thickness and the conditions under which the samples dry--from direct sunlight to total darkness in a cool place. (2 IT, 1 N, 3 ET)

Demonstrate mudcrack formation. Soak clay in salt water overnight. Repeat the above procedure and compare the mudcracks formed in salt water to those formed in fresh water. (1 IT, 2 N, 3 ET)

Examine a variety of fossiliferous rock, and note size, abundance, and types of fossils. (2 N, 4 ET)

Projects

Produce deltas and alluvial fans by spraying a mound of dirt at a construction site on campus with a hose. At the base of the mound spread out a large piece of plastic which will "pond" the runoff, and allow the sediment to settle in a body of water. Drain the lake and slice into the delta. Compare the cross-section of the delta formed with that of an alluvial fan formed at the base of the slope. (1 IT, 1 N, 4 ET)

Reference

B-13: Water Abrasion, pp. 213-227.

C. Stratigraphy

1. Basic Laws

2. Stratigraphic Columns

3. Breaks in the Rock Record

Concept

Sedimentary rocks are usually deposited on a horizontal surface with the oldest rocks being on the bottom of an exposure.

Activities

Provide the student with sufficient data, and have him construct a stratigraphic column from data provided by the teacher. (1 IT, 1 N, 4 ET)

Construct two stratigraphic columns for two distant points and correlate strata from the data provided by the teacher. (1 N, 5 ET)

Projects

Investigate the history of the origin of the geologic time scale. Discuss the importance of rock units, time units, and time-rock units.

D. Sedimentary Rocks

1. Clastic

2. Non-Clastic

3. Mineral Composition of Sedimentary Rocks

Concept

Sedimentary rocks can be classified according to the nature of the particles or the manner in which the particles were formed.

Activities

Examine the following sedimentary rocks, and propose a system for classifying the following sedimentary rocks: sandstone, shale, siltstone, arkose, breccia, conglomerate, graywacke, and limestone. (1 N, 5 ET)

Examine thin sections of sandstone, shale, siltstone, arkose, breccia, conglomerate, graywacke, and limestone, and contrast their microscopic appearance to their hand specimen characteristics. (2 N, 4 ET)

Note the variety of minerals which appear in hand specimens of sedimentary rocks when examined under a binocular microscope. (2 N, 4 ET)

Section A: Unit Outline

VII. The Composition of the Crust

A. Minerals

1. Chemical Considerations

2. Physical Properties of Minerals

B. Rock Forming Minerals

1. Non-Silicates

2. Silicates

C. Reaction of Minerals to Weathering

1. Physical Weathering

2. Chemical Weathering

D. Mineral Ores Resulting from Weathering

1. Iron Deposits

2. Bauxite Deposits

3. Placer Deposits

4. Secondary Enrichment

Section B: Concepts and Related Behavioral Objectives

VII. The Composition of the Crust

A. Minerals

1. Chemical Considerations

2. Physical Properties of Minerals

Concept

Stress caused by atomic forces causes chemical reactions to occur and products stable in the reacting environment are formed.

Behavioral Objectives

A student should be able to:

Use a neatly constructed and labelled diagram to contrast two elements as they occur in the atomic state with their relationship when united as a compound. For example: hydrogen and oxygen as compared to a molecule of water.

Give examples of the three types of basic chemical reactions: synthesis, analysis, and replacement.

Concept

Crystals are external expressions of materials which have a regular internal arrangement of atoms or molecules.

Behavioral Objectives

A student should be able to:

Diagram the crystallographic axial relationship for each of the six crystal systems.

Use the Law of Conservation of Energy to explain why a supersaturated solution becomes hot upon crystallization, and why a dehydrated crystal becomes hot when water is added.

Name two minerals which exhibit one, two, and three directions of cleavage.

Define birefringence, and use a diagram to explain how this property is exhibited in a calcite crystal.

List the similarities and differences between a diffraction spectrum produced when muscovite mica and layers of scotch tape are examined through crossed polars.

Concept

Minerals are naturally occurring, inorganically formed compounds which have definite chemical characteristics and physical properties.

Behavioral Objectives

A student should be able to:

Define specific gravity, and illustrate three ways this property could be determined in a laboratory.

Explain in what respects Moh's Hardness Scale is called a "relative scale."

B. Rock Forming Minerals

1. Non-Silicates

2. Silicates

Concept

The wide variety of silicate minerals is due to the abundance of the elements oxygen and silicon in the earth's crust, and the variation in which these two atoms can be arranged in molecular form.

Behavioral Objectives

A student should be able to:

Explain why the Radius Ratio is the governing factor in determining the Co-ordination Number of an element.

Identify at least three oxide, sulfide, carbonate, sulfate, and silicate minerals.

C. Reaction of Minerals to Weathering

1. Physical Weathering

2. Chemical Weathering

Concept

Minerals weather under conditions which are inversely related to the conditions under which they were formed.

Behavioral Objectives

A student should be able to:

List several factors which affect the rate at which a mineral will undergo chemical weathering. Cite examples.

Illustrate how the Bowen's Reaction Series can be used as an index for mineral weathering.

D. Mineral Ores Resulting from Weathering

1. Iron Deposits

2. Bauxite Deposits

3. Placer Deposits

4. Secondary Enrichment

Concept

Through the weathering process, valuable mineral ores often accumulate.

Behavioral Objectives

A student should be able to:

Explain how a climatological map can be used to locate areas where bauxite might be found.

Define the term, secondary enrichment, and list three ores which are formed through this process.

Section C: Concepts and Related Laboratory Activities

VII. The Composition of the Crust

A. Minerals

1. Chemical Considerations

2. Physical Properties of Minerals

Concepts

Stress caused by atomic forces causes chemical reactions to occur and products stable in the reacting environment are formed.

Activities

Perform chemical reactions which illustrate synthesis, analysis, and replacement. For the synthesis experience, heat fine iron powder and sulfur. Decompose mercuric oxide for the analysis. Drop a piece of copper wire into a silver nitrate solution for the

replacement reaction. Observe the latter under a binocular microscope. (1 N, 5 ET)

Concept

Crystals are external expressions of materials which have a regular internal arrangement of atoms and molecules.

Activities

Heat copper sulfate crystals in a test tube to illustrate heat of crystallization. Let the dehydrated powder cool, and then add a few drops of water to the test tube, and shake. (3 N, 3 ET)

Mix water with Plaster of Paris to illustrate heat of crystallization. Record the temperature of the water used, and the temperature of the gypsum as it sets. (5 N, 1 ET)

Prepare supersaturated solutions of sodium acetate or sodium thiosulfate. Divide the solution into four or five clean test tubes, and allow to cool. Drop a seed crystal into one test tube and observe with a binocular microscope. Place your thumb over another, and shake. Pour the contents of the third onto the table. Put a wire into the fourth test tube for a few seconds, and withdraw. Examine the wire under a binocular microscope. (1 N, 5 ET)

Sodium hydroxide is a compound whose hydration energy is greater than its lattice energy, so energy is given off when it dissolves in water. Dissolve some pellets of sodium hydroxide in a small quantity of water, and record the temperature change. (1 N, 5 ET)

Examine minerals with good crystal cleavage: quartz, feldspars, galena, pyrite, and halite.

Cleave a calcite crystal with a hammer and knife blade. Place the knife parallel to a cleavage surface and hit with a hammer. Examine the fragments and the powder under a binocular microscope. (6 ET)

Examine light wave interference in a natural crystal by observing muscovite between crossed polars. If there is an insufficient number of polarizers for each student, perform this exercise on an overhead projector. (2 N, 4 ET)

Examine light wave interference by observing varying thicknesses of scotch tape between crossed polars. Stagger pieces of tape on a glass so that varying thicknesses are visible. Place between crossed polars, and use an overhead projector if desired. Compare the thicknesses of tape to the layers of mica. (3 N, 3 ET)

View the double refraction properties of a calcite crystal. Place the crystal on a page in the textbook. (1 N, 5 ET)

Demonstrate the double refraction properties of a calcite crystal by using an overhead projector. Prick a pin hole through an index card, and place on the overhead projector. Place a calcite crystal on top of the hole, and observe the two holes on the overhead screen. (1 N, 5 ET)

Observe the behavior of light as it passes through mineral crystals by examining crushed halite, calcite, feldspar, and quartz through a polarizing microscope. (1 N, 5 ET)

Projects

Make a photographic record of the reaction of copper wire and silver nitrate solution. Photograph the reaction through a microscope. (1 IT, 3 N, 2 ET)

Make a photographic exhibit showing crushed halite, calcite, feldspar, and quartz as they are rotated on the stage of a polarizing microscope. Contrast pictures made in plane and polarized light. (1 IA, 1 IT, 2 N, 2 ET)

References

B-8: Crystal Recipe, pp. 1-60.
B-11: Crystal Growing, pp. 74-93.
B-15: Interference Colors, pp. 32-36.

Concept

Minerals are naturally occurring in organically formed compounds which have definite chemical characteristics and physical properties.

Activities

Determine the specific gravity of various minerals. Use heavy liquids, a Jolly Balance, and the standard water displacement methods. (6 ET)

Compute the density of a piece of galena. When all students have completed their density calculations, use their data and plot a graph which relates mass to volume. What does the line connecting the points represent? (1 N, 5 ET)

Compute the density of an ice cube. Use water, alcohol, graduate cylinder, and an ice cube. (1 IT, 2 N, 3 ET)

Determine the hardness of at least six minerals. Arrange the minerals in order of hardness. Provide students with an iron file, a penny, a piece of glass, and arrange the minerals and objects in order of their hardness. (1 N, 5 ET)

Project

Fill a graduate cylinder with various liquids to demonstrate density layering. Use water, glycerine, mineral oil, isopropyl alcohol. (2 N, 4 ET)

Demonstrate the meaning of specific gravity by filling small vials with various elements, compounds, and minerals. Compare the weight of these vials with a similar vial of water. (2 IT, 4 ET)

Concept

The wide variety of silicate minerals is due to the abundance of elements oxygen and silicon in the earth's crust, and the variation in which these two atoms can be arranged in molecular form.

Activities

Use styrofoam spheres of various sizes to experimentally determine radius ratios. (2 IT, 4 N)

Construct various silicate structures using styrofoam spheres. (2 IT, 3 N, 1 ET)

C. Reaction of Minerals to Weathering

1. Physical Weathering

2. Chemical Weathering

Concept

Minerals weather under conditions which are inversely related to the conditions under which they were formed.

Activities

Illustrate the pressure caused by freezing water by having students fill vials with water and placing them in the freezer. Put the vials in a plastic baggie to prevent broken glass from freezing to the freezing compartment. (1 IT, 1 N, 4 ET)

Demonstrate the effects of frost heaving by filling several beakers with soil, and then adding water. Place in the freezer, and note the level of the frozen soil the next day. (2 N, 4 ET)

Demonstrate the effects of frost heaving by soaking cubes of clay in water and then placing the samples in the freezer. Examine when frozen. (2 N, 4 ET)

Arrange for a mineral to oxidize by crushing a piece of pyrite, and wetting it. Allow to dry and then rewet. Continue for several days. (1 IT, 3 N, 2 ET)

Arrange for an element to oxidize by wetting steel wool, and letting it set for several days. (2 N, 4 ET)

Arrange for an element to oxidize by placing a piece of steel wool into some water to which three teaspoons of chlorox and one teaspoon of acetic acid has been added. (1 IT, 4 N, 1 ET)

Projects

Using a binocular microscope, make a photographic record of steel wool oxidizing. Contrast the two rates of oxidation in the two activities above in a photographic essay. (1 IT, 4 N, 1 ET)

Using a binocular microscope, make a photographic record of pyrite oxidizing in water. 1 IT, 1 N, 4 ET)

D. Mineral Ores Resulting from Weathering

1. Iron Deposits

2. Bauxite Deposits

3. Placer Deposits

4. Secondary Enrichment

Concept

Through weathering processes, valuable mineral ores often accumulate.

Activity

Prepare a three part display which relates the geologic, economic, and chemical considerations of some mineral. Type a one page summary of the mineral's properties and geological importance. The second page should contain a map of the areas where the principal mines are located. The third page is a graph which shows the percent composition, by weight, of each element composing the mineral. (2 IT, 2 N, 2 ET)

Project

Write to various mining companies to secure teaching aids, samples of their ores and other information concerning their mining operations. (1 IT, 4 N, 1 ET)

In May, 1970, a vice-president of Bethlehem Steel's plant in Marshall's Branch, Kentucky, branded all those people who are interested in reclaiming strip mining areas as idiots and Communists. Write to David A. Zageer, Bethlehem Steel Corporation, Marshall's Branch, Kentucky. As for information concerning their strip mining operations, and their land reclamation program. (2 N, 4 ET)

Write to Senator Gaylord Nelson in Washington, D. C., to obtain information concerning the Federal Mine Lands Restoration Act which he supports. (6 ET)

Section A: Course Outline

VIII. Formation of Igneous Rocks

A. Causes of Igneous Activity

1. Geothermal Gradient

2. Magma Origin and Movement

B. Types of Igneous Activity

1. Intrusive Rocks Formations

2. Extrusive Rock Formations

C. Igneous Rocks

1. Crystallization

2. Chemistry

Section B: Concepts and Related Behavioral Objectives

VIII. Formation of Igneous Rocks

A. Causes of Igneous Activity

1. Geothermal Gradient

2. Magma Origin and Movement

Concept

Heat released from the decay of radioactive minerals causes the temperature of the earth to increase with depth, but rocks do not melt at high temperatures due to high confining pressures.

Behavioral Objectives

A student should be able to:

Use basic ideas of atomic physics to explain the cause of the geothermal gradient.

Use the kinetic theory to explain why rocks deep in the crust do not exist as liquids even though the temperature is beyond their melting point.

B. Types of Igneous Activity

1. Intrusive Rock Formations

2. Extrusive Rock Formations

Concept

Igneous activity does not always express itself through volcanic eruption. Large scale magmatic activity may occur in an area without visible signs at the surface of the earth.

Behavioral Objectives

A student should be able to:

Classify volcanoes as to their activity, type of lava, and cone composition. Identify shield and composite cones on a topographic map.

Use a diagram to explain how it is possible to differentiate a sill from a buried lava flow.

Use a diagram which illustrates the difference between a sill, a laccolith, a boatholith, and a dike.

C. Igneous Rocks

1. Crystallization

2. Chemistry

3. Types of Igneous Rocks

Concept

The texture and chemical composition of an igneous rock serves as a basis for identification.

Behavioral Objectives

Describe an experiment which illustrates the effect of cooling rate on crystal formation.

Explain how rock texture and chemical composition can be used to classify igneous rocks.

Identify samples of the following rocks: granite, gabbro, rhyolite, basalt, porphyry, vesicular basalt, diorite, and andesite.

Section C: Concepts and Related Laboratory Activities

VIII. Formation of Igneous Rocks

A. Causes of Igneous Activity

1. Geothermal Gradient

2. Magma Origin and Movement

Concept

Heat released from the decay of radioactive minerals causes the temperature of the earth to increase with depth, but rocks do not melt because of high confining pressures.

Projects

Obtain a man-made isotope, and determine the half-life of the element. Three weeks of readings are sufficient to determine the half-life and the identity of the element. Report on the chemistry and

physics of radioactivity, and the radioactive elements in granites and basalts.

Examine the topic of radioactive dating of rock samples, and discuss the chemistry, physics, advantages, and disadvantages of the uranium-lead, potassium-argon, and radiocarbon methods of dating.

Examine the topic of heat flow in the earth's crust. Discuss how these measurements are made, the magnitude of the readings recorded at various points on earth, and the inferences drawn from such data. (1 IT, 1 N, 4 ET)

B. Types of Igneous Activity

1. Intrusive Rock Formations

2. Extrusive Rock Formations

Concept

Igneous activity does not always express itself through volcanic eruption. Large scale magmatic activity may occur in an area without visible signs at the surface of the earth.

Activity

Examine the following topographic maps which illustrate the effects of igneous activity: Menan Buttes, Idaho; Paxton Springs, New Mexico; Crater Lake, Oregon; Shasta, California; Ship Rock, New Mexico. (6 ET)

References

B-1: Igneous Geology, pp. 136-138.
B-5: Volcanoes, pp. 75-80.
B-12: Vulcanism, pp. 165-176.
B-13: Rise of Molten Rock in the Earth's Crust, pp. 257-269.
B-16: Landforms Produced by Volcanic Activity, pp. 48-49.

C. Igneous Rocks

1. Crystallization

2. Chemistry

Concept

The texture and chemical composition of an igneous rock serve as a basis for identification.

Activities

Experimentally determine if the rate of cooling affects the size of crystals produced from a melt. Pour melted alum cyrstals into three petrie dishes. Let one dish float in an ice bath, and another float in a hot bath. Allow the third to cool on the table top. (6 ET)

Examine a variety of igneous rocks under a binocular microscope. Note the variety, size, and shape of the component minerals. (1 N, 5 ET)

Project

Examine the topic of eutectic points. Make solder by using powdered forms of tin and lead mixed with sodium carbonate (to prevent oxidation). Solder melts at 220° C, but tin melts at 232° C, and lead melts at 327° C. Report on the melting points of other alloys as opposed to the melting points of the alloy components. (1 IA, 1 IT, 3 N, 1 ET)

Section A: Course Outline

IX. Rock Deformation and Metamorphism

A. Bending the Earth's Crust--Folds

1. Types of Folds

2. Viewing the Deformed Crust

B. Breaking the Earth's Crust--Faults

1. Slip Dip Faults

2. Slip Strike Faults

C. Metamorphism

1. Agents of Metamorphism

2. Types of Metamorphism

3. Metamorphic Rocks

Section B: Concepts and Related Behavioral Objectives

IX. Rock Deformation and Metamorphism

A. Bending the Earth's Crust--Folds

1. Types of Folds

2. Viewing the Deformed Crust

B. Breaking the Earth's Crust--Faults

1. Slip Dip Faults

2. Slip Strike Faults

Concept

The rate at which stress is applied to solids causes them to break or flow.

Behavioral Objectives

A student should be able to:

Use a diagram to explain the difference between symmetrical, asymmetrical, recumbent, and isoclinal folding.

Solve three point problems when given sufficient data.

Construct a block diagram which illustrates a specified geological setting.

Use a neatly constructed and labelled diagram which illustrates Gravity, Reverse, and Thrust Faults.

Use a neatly constructed and labelled diagram which illustrates Dextral and Sinistral Faults.

C. Metamorphism

1. Agents of Metamorphism

2. Types of Metamorphism

3. Metamorphic Rocks

Concept

When heat and pressure are combined with chemical activity within the earth, sedimentary and igneous rocks undergo changes in texture and chemical composition.

Behavioral Objectives

A student should be able to:

Identify the following metamorphic rocks: quartzite, marble, slate, phyllite, schist, and gneiss.

Section C: Concepts and Related Laboratory Activities

IX. Rock Deformation and Metamorphism

A. Bending the Earth's Crust--Folds

1. Types of Folds

2. Viewing the Deformed Crust

B. Breaking the Earth's Crust--Faults

1. Slip Dip Faults

2. Slip Strike Faults

Concept

The rate at which stress is applied to solids causes them to break or flow.

Activities

Solve three point problems in the laboratory by using a small box, sand, wire, and a piece of cardboard. Lay the cardboard so it forms the diagonal (from top to bottom) in a box. Cover the cardboard with sand or soil. Use stiff wire or glass tubing to represent "wells." Measure the depth at which the wire strikes the cardboard. This cardboard represents the buried strata. Measure the distances and angles between the three "wells," and solve the three point problem. (1 IT, 1 N, 4 ET)

Solve three point problems on the lawn. Choose three points such as trees, posts, corners of buildings, and attach to each position a card bearing information about a ficticious strata. For example: "At this position the depth of the Hogwash Formation is 150 ft." Students must determine the distance between the three points, and the compass direction between these points, and solve the three point problem. (1 IT, 3 N, 2 ET)

Use a shoebox or some other small box to make block diagrams. Provide the students with data concerning strike, dip, and thickness of strata. (1 IT, 2 N, 3 ET)

Use index cards to illustrate types of faults. Draw horizontal strata on the card, and cut the card to illustrate Reverse and Normal Faults. (1 IT, 2 N, 3 ET)

Use index cards to illustrate complex faults. Draw horizontal strata on the card, and cut the card to illustrate some type of fault. Displace the strata, and tape the card together. Cut the first fault with another fault, and displace strata. Tape the cards together. Trim the cards to a rectangular shape, and view the doubly offset strata. (2 IT, 2 N, 2 ET)

References

B-1: Structural Geology, pp. 114-135.
B-6: Structural Geology, pp. 83-116.
B-12: Geologic Structure, pp. 49-70.
B-16: Structural Geology, pp. 51-69.

C. Metamorphism

1. Agents of Metamorphism

2. Types of Metamorphism

3. Metamorphic Rocks

Concept

When heat and pressure are combined with chemical activity within the earth, sedimentary and igneous rocks undergo changes in texture and chemical composition.

Activity

Examine samples of quartzite, marble, slate, phyllite, schist, and gneiss. Propose a basis for classifying metamorphic rocks. (1 N, 5 ET)

Project

Examine the effects of heat on clay. Take a photomicrograph of soft clay. Using a kiln, subject clay samples to various temperatures and for varying lengths of time. Compare photomicrographs of baked and soft clay samples. (1 IT, 2 N, 3 ET)

References

B-12: Metamorphic Rocks, pp. 31-38.
B-16: Metamorphic Rocks, pp. 12-15.

Section A: Unit Outline

X. The Solid Earth

A. Earthquakes

1. The Earth Vibrates

2. Locating the Vibration Source

3. Decoding the Vibrations

B. Geomagnetism

1. The Physics of Magnetism

2. Paleomagnetism

3. Continental Drift

C. Orogeny

1. Geosynclinal Theory

2. Isostasy

Section B: Relation of Concepts and Behavioral Objectives

X. The Solid Earth

A. Earthquakes

1. The Earth Vibrates

2. Locating the Vibrating Source

3. Decoding the Vibrations

Concept

Interpretation of the physical characteristics of earthquake waves reveals information concerning the structure and the composition of the earth's interior.

Behavioral Objectives

A student should be able to:

List evidence which supports the idea that the density of earth materials increases with depth.

Contrast the physical properites of P-waves and S-waves.

Locate the epicenter of an earthquake when supplied with sufficient data.

Construct a model of the earth's interior, and support the parameters of this model by citing evidence obtained through ine interpretation of earthquake waves.

Explain what the presence of a Shadow Zone infers about the structure of the earth.

B. Geomagnetism

1. The Physics of Magnetism

2. Paleomagnetism

3. Continental Drift

Concept

Because of their unique electron configuration, a magnetic field may be induced in certain elements, alloys, and compounds.

Behavioral Objectives

A student should be able to:

Explain what is meant by the statement: Magnets will only attract other magnets.

Explain the relationships between magnetism and electricity by using the Oersted and Faraday experiments.

Concept

Induction caused by the earth's magnetic field produces magnetism in elemental iron and iron compounds as they cool from the molten state.

Behavioral Objectives

A student should be able to:

Explain the difference between magnetic declination and magnetic dip.

Explain why compass points are referred to as north seeking and south seeking poles.

List several factors which must be taken into consideration when interpreting paleomagnetic data, and explain why these factors are important.

Concept

Paleomagnetic data from rocks of various ages and locations around the work is interpreted to prove that the positions of the poles and the continents have changed with time.

Behavioral Objectives

A student should be able to:

List and explain five types of evidence which indicate that the continents have drifted.

List and explain five types of evidence which indicate that the continents have not drifted.

C. Orogeny

1. Geosynclinal Theory

2. Isostasy

Concept

Many mountain chains around the world appear to have had a history which included periods of deposition, deformation, and uplift. Such mountains are said to be geosynclinal in origin.

Behavioral Objectives

Cite evidence which supports the geosynclinal theory of moutain formation.

Define the terms eugeosyncline, miogeosyncline, craton, island archipelago, and explain how these terms relate to the history of a mountain range.

Concept

Even when corrections for mass and elevations are considered, the acceleration of gravity around the world is not constant.

Behavioral Objectives

Contrast the theories of isostasy as proposed by Pratt and Airy, and cite evidence which supports each theory.

Compute the acceleration of gravity using the pendulum method.

Solve problems dealing with flotation.

Propose theories which would explain the existence of gravity anamolies.

Section C: Relation of Concepts and Laboratory Activities

X. The Solid Earth

A. Earthquakes

1. The Earth Vibrates

2. Locating the Vibration Source

3. Decoding the Vibrations

Concept

Interpretation of the physical characteristics of earthquake waves reveals information concerning the structure and the composition of the earth's interior.

Activities

Use slinkies to contrast the behavior of compressional and shear waves. (5 N, 1 ET)

Use prisms to examine the refraction of light. Contrast light wave refraction to earthquake wave refraction. (1 IT, 3 N, 2 ET)

References

B-6: Seismology, pp. 165-179.
B-12: The Earth, pp. 176-186.
B-13: Bending and Breaking the Earth's Crust, pp. 270-280.

B. Geomagnetism

1. The Physics of Magnetism

2. Paleomagnetism

3. Continental Drift

Concept

Because of their unique electron configuration, a magnetic field may be induced in certain elements, alloys, and compounds.

Activities

Make a magnet from a needle. Induce a magnetic field in the needle by stroking the needle in one direction with a magnet. (3 IT, 1 N, 2 ET)

Support a magnet on a string, and let the magnet assume a fixed position. (1 A, 3 IT, 1 N, 2 ET)

Study the effects of magnetism produced in an object by the earth's magnetic field. Hold a compass at the top of a radiator or some other stationary piece of metal in the room. Note which end of the compass is attracted to the radiator. Move the compass

to the bottom of the radiator and note which end of the compass is attracted to the radiator. (3 N, 3 ET)

References

B-6: Geomagnetism, pp. 181-191.
B-14: Determining the Horizontal Vector of the Earth's Magnetic Field, pp. 281-286.

Project

Write to one of the companies which produce color television sets. Ask for information concerning their assembly lines: do they run east-west or north-south? What precautions are taken to insure that the building is totally demagnetized? How do they demagnetize an entire building, and why? (1 IT, 2 N, 3 ET)

C. Orogeny

1. Geosynclinal Theory

2. Isostasy

Concept

Many mountain chains around the world appear to have had a history which included periods of deposition, deformation, and uplift. Such mountains are said to be geosynclinal in origin.

Reference

B-3: Geosynclines, pp. 379-383.

Concept

Even when corrections for mass and elevations are considered, the acceleration of gravity around the world is not constant.

Activities

Determine the acceleration due to gravity by using the pendulum method. (2 N, 4 ET)

Review the physics of flotation. Divide students into groups and quantitatively solve problems using three liquids: alcohol, water, mercury. (3 N, 3 ET)

Project

Make a floating model which illustrates the difference between the Pratt and Airy theories of isostasy. (5 N, 1 ET)

Examine the yellow pages of several area telephone directories. Obtain names and addresses of various enterprises where geologically related information could be obtained. Example: sand and gravel pits, surveyers, quarry operations, well diggers, etc. Type this information and reproduce copies for distribution to students. (3 N, 3 ET)

References

B-1: Crustal Depression, pp. 110-113.

CHAPTER V

IMPLICATIONS OF THE STUDY

Report From the Panel

Panel members rated 106 laboratory activities and 45 student projects. From the manner in which the activities and projects were scored, no pattern was evident which identified the geologist from the science educator. Differences were noted which reflected the geological location and interest of the panelist.

1. Field trips by the Wisconsin reviewer enabled students to view rocks with a variety of geologic periods. Thus, he thought that the geologic time scale should be studied in greater depth.

2. Specializing in glacial deposits and geomorphological processes, the Massachusetts reviewer questioned the value of hoseing a mound of dirt with water, when more detailed studies can be obtained by using a stream table such as they have at Amherst College.

3. Stationed on the west coast of Florida, another reviewer suggested that a section regarding wind erosion, and some more activities regarding sea shore processes, be added to the curriculum guide.

4. Raised and trained in New York state, another reviewer stated what the other panelists were inferring: the beginning course in geology should concentrate on the geology of the local environment. Students should study the materials present, and those important geologic processes that are manifested in the immediate area.

Everyone agreed that the conceptual schemes developed for the course were adequate. The concepts stated in the guide were declared to be essential for the development of the conceptual schemes. Suggestions were received regarding the addition of activities to the curriculum guide. Any activity that was added to the guide as a direct of indirect suggestion of a panel member is not followed with a parenthetical score.

Interesting comments regarding certain projects were received from two panel members. One panelist was very skeptical of the types of responses students could elicit during an interview with a city official or when writing to a company or government

agency for information. He thought that, whenever possible, a representative from a company or city office should visit the class and answer questions from the entire class. His rationale for this type of activity was simple:

> I feel that this would eliminate student frustrations in getting the standard advertising "spiel", or public relations "snow job" about such and such company.

City bureaucrats and company officials might be reluctant to submit themselves to any type of interview, was the comment of another panelist. He also pointed out that, in the highly competative business of well drilling, it is unlikely that a well digger would freely part with information concerning the depth and location of wells. Both points are well made. Let the interviewer beware.

Negative reaction to the idea of beginning the course with a study of processes of geology rather than the materials of the earth was received from one panelist. He tried to teach geology in such a manner, but found that both the geology major and the nonmajor preferred studying rocks and minerals first. No other comments, positive or negative, were received regarding this facet of the course.

Suggestions for Further Study

Blueprinting a course of study is one task, and measuring the success of such a curriculum is another matter. No attempt has been made to compare the teaching in this course to that of

the traditional physical geology course. Test and control groups would have to be determined, and a suitable instrument designed to measure the attainment of course objectives. Such statistical analysis of course effectiveness could be measured over several semesters.

Greater detail could be given to the behavioral objectives and associated activities. Objectives relating to the cognitive domain could be arranged in a hierarchal sequence, with prerequisite objectives and activities noted. Also, objectives which pertain to the affective and psycho-motor domains could be specified.

The Author Reflects

Dissertations are conceived in the mind and incubated by hours at the typewriter. Originally, the author planned to design the course for a specific geologic location,but this plan was never realized. The author believes that the resultant study will be of greater value to himself and to the reader. Because many units of study were discussed, the reader can examine a variety of activities dealing with all facets of geology. He is provided with guidelines for expanding any one topic in a manner which is commensurate with the natural resources of his particular area.

Surficial merit ratings have been registered regarding the value of the activities and projects. The real value of these exercises must be measured against their ability to meet the stated objectives during the semesters when the course is taught.

Unique to this study was the curriculum rationale in which those environmental problems with geological implications are used as an integrating construct to eclectically balance the curriculum building forces of society, knowledge, and the learner.

Ability to solve any of the mammoth environmental problems facing our society should not be equated with a student's success in this course. It is hoped that this course will provide the student with an enlightened attitude toward environmental problems, and equip him with the basic skills needed to undertake additional study regarding this topic.

Should this program ignite student interest to further pursue the relevant topics of geology, and cause teachers to re-examine their course content, goals, and methods, then the study has been worthwhile.

APPENDIX A

Members of the Panel of Reviewers:

1. Dr. N. E. Bingham, Chairman
   Department of Science Education
   University of Florida
   Gainesville, Florida 32601

2. Mr. Joseph Caggaino, Graduate Assistant
   Geology Department
   University of Massachusetts
   Amherst, Massachusetts 01002

3. Dr. Richard Edwards
   Geology Department
   University of Florida
   Gainesville, Florida 32601

4. Mr. Vincent Greico, Graduate Assistant
   Geology Department
   University of Buffalo
   Buffalo, New York 14214

5. Dr. Marvin Ivey, Chairman
   Department of Natural Science
   St. Petersburg Junior College
   St. Petersburg, Florida 33733

6. Mr. Donald Mikolajczak
   Natural Science Department
   Milwaukee Technical College
   Milwaukee, Wisconsin 53203

APPENDIX B

References cited in the curriculum guide:

B-1 Bick, Kenneth F., and Gerald H. Johnson. Laboratory Manual in Earth Science. New York: Thomas Y. Crowell Company, 1967.

B-2 Earth, Teacher's Guide Investigating the. Part I. Earth Science Curriculum Project. New York: Houghton Mifflin Company, 1967.

B-3 Earth, Teacher's Guide Investigating the. Part II. Earth Science Curriculum Project. New York: Houghton Mifflin Company, 1967.

B-4 Evans, Thomas P. "Water Sampling Apparatus and Determining of Dissolved Oxygen in Water." Science Teacher. 36:56-67, May 1969.

B-5 Floch, Henri J. Workbook for (Ramsey and Burckley) Modern Earth Science. New York: Holt, Rinehart and Winston, Inc., 1962.

B-6 Gilbert, Charles M., and Mark N. Christensen. Physical Geology Laboratory Course. New York: McGraw-Hill Book Company, 1967. Second Edition.

B-7 Heller, Robert L., Editor. Geology and Earth Sciences Sourcebook for Elementary and Secondary Schools. New York: Holt, Rinehart and Winston, Inc., 1962.

B-8 Holden, Alan,and Phyllis Singer. Crystals and Crystal Growing. Garden City, New York: Anchor Books, Doubleday and Company, 1960.

B-9 Joesph, Alexander, et al. Teaching High School Science: A Sourcebook for the Physical Sciences. New York: Harcourt,Brace and World, Inc., 1961.

B-10 Marean, John H., et al. Laboratory Record Book for Earth Science A Laboratory Approach. Reading, Massachusetts: Addison-Wesley Publishing Company, 1970.

B-11 Marean, John H, and Elaine W. Ledbetter. Physical Science A Laboratory Approach Investigating Matter and Energy. Reading, Massachusetts: Addison-Wesley Publishing Company, 1968.

B-12 Miller, John P., and Robert Scholten. Laboratory Studies in Geology. San Francisco: W. H. Freeman and Company, 1966.

B-13 Navarra, John Gabriel, and Arthur N. Strahler. Our Planet in Space The Earth Sciences. New York: Harper & Row, Publishers, 1969.

B-14 Sund, R. B., and L. W. Trowbridge. Teaching Science by Inquiry in the Secondary School. Columbus, Ohio: Charles E. Merrill Books, Inc., 1967.

B-15 Wood, Elizabeth A. Experiments With Crystals and Light. Bell Telephone Laboratories, Incorporated, 1964.

B-16 Zumberge, James H. Laboratory Manual for Physical Geology. Dubuque, Iowa: William C. Brown Company, 1967. Third Edition.

APPENDIX C

Field Trip Guide

Underdeveloped pictures of the geological sciences are all that can be developed by the teacher in the classroom. Models, 35 mm slides, graphs, charts, and maps are essential for the study of any science, but when these activities totally replace actual field experience, the structure of the course is poorly lithified, and the portrait painted by the teacher is not representative of the spirit of inquiry afforded through the study of science.

Collection of geological data is not a simple matter, for the plans of the geologists are often altered when he finds the river channel flooded, a fault surface covered by a recent slump, and an exposure inaccessible. Such experience is not conveyed by words and pictures. Students must experience the problem of taking data in the field and the feeling of success and frustration encountered in the study of real problems. Without field study, geology becomes a subject concerned with "water on a stream table, and rocks in a box."

All geographic regions do not allow students to experience direct field activities for each topic discussed in the curriculum guide. With the possible exception of one topic, a field guide cannot be prepared which would be suitably used regardless of the location of the reader. The one topic which lends itself to

universal study is water--stream and ground water supplies.

Complete with behavioral objectives, field activities are listed here for a trip concerned with the study of stream and ground water supplies. It is hoped that this guide will serve as a model and source of ideas for the preparation of other trips dealing with such topics as rocks, minerals, glaciers, structural geology--that is, those trips in which the intensity of exploration depends upon the geographic location of the reader. Possible activities for such trips are listed in the second half of this field guide, but it is left for the reader to develop specific objectives and the types of activities he would care to perform.

Regardless of the topic studied, there is a common core of goals for any field trip. It is the opinion of the author that field study . . .

1. . . . allows students to observe natural geologic forces in action, and to quantitatively investigate the role these forces have in sculpturing the earth's crust,

2. . . . portrays science as a continuing process of inquiry which requires observation, collection of data, analysis, and making interpretations,

3. . . . permits the student to become involved with problem-solving situations in which solutions are found through library research, laboratory investigations, field observations, and consultation with authorities,

4. . . . engenders an awareness that data collection is a task which often presents many difficult problems,

5. . . . illustrates the delicate balance which exists between man controlling his environment and the environment controlling man, and

6. . . . demonstrates that geology is not only a science with many practical applications, but is a field where active theoretical studies take place.

Field Trip One: Surface and Ground Water

Behavioral Objectives.

A student should be able to:

1. Describe two methods used to determine the gradient of a stream.

2. Explain the relationship between channel size and stream velocity by citing the data collected.

3. Describe the techniques used in an experiment, and discuss the limitations of an experiment used to determine the amount of dissolved solids carried in a stream.

4. Describe some erosional and depositional features of streams and identify these characteristics on a topographic map.

5. Manipulate various pieces of data collecting equipment and explain how and why each are used.

6. List several technical and geological problems involved in drilling a well.

7. Explain the effects that dissolved solids have on man's use of ground water supplies.

Field Trip One: Surface and Ground Water

Efficiency in field work is essential. Because of the many parameters involved in this initial field experience, students should be assigned to a small group, and each group will study one aspect of streams and/or ground water. Data collection for any

group should take less than 20 minutes so students will then be free to observe other groups recording their observations. During a laboratory session each group will have a chance to present their findings, and the data for the entire trip can then be collated. Such reports will allow students to explain the problems they encountered and surmounted in obtaining their data.

Streams:

1. Gradient--Determine the stream gradient in two places; one where the stream channel is wide and another where the stream channel is narrow. They will determine the change in elevation and the distance as it is measured in a straight line and as it is measured along the stream bed.

2. Velocity--The velocity and cross-sectional area of the stream will be measured at two selected spots, as was the gradient determination. The cross-sectional area should be measured at the mid-point of the distance used to measure the velocity.

3. Water pH--Collect water samples and record temperature and pH. The latter should be measured with pH paper and a portable pH meter. Record the pH and temperature every 10 minutes until no change is noted. Colorimetry methods might be another method used to determine pH.

4. Photographic Record--This is an ideal project for a student who is "science shy," but yet has an interest in photography. Another student should be assigned to record information about the photograph--exposure setting, location of photography, a description of stream bed, stream channel, vegetative cover of the watershed area, etc. If possible, samples of the item being photographed should be collected. When the photographs are processed, a bulletin board should be arranged. The location of the photograph should be noted on a topographic map, and the samples of soils, stream bed rocks, etc., displayed.

Ground Water:

After lunch, the class will meet with a well digger at a specified location. He will explain the mechanics of well drilling, equipment used, problems encountered, etc.

1. Auger Samples--Collect samples of soil and rock brought up from the drill. Record depth of sample, condition, texture, water content of sample.

2. Well Water--Stop at several farm houses and inquire about the use of wells in the area. Ask such questions regarding well depth, date of drilling, problems encountered, septic tank dangers and problems, type of pump used, type of water softener used. Obtain a sample of well water and determine the dissolved solids content. Write to water pump manufacturers and obtain information regarding the variety of pumps they make.

3. Well Depth--Interview the well driller and obtain well logs of the area. Plot the depth and location of these wells on a topographic map.

Field Trip Two: The Materials of the Earth

1. Road Cuts--Other than the inherent traffic problems caused by students exploring a road cut, they offer one of the most efficient methods of getting to an outcrop, collecting samples, and moving to a new location. Many interstate highways cut through beautiful rock and mineral areas, and the rest areas allow visitors to examine the exposure.

   Photographic Record--Photograph all aspects of the trip: rock stratification, fault surfaces, ripple marks, minerals, in situ, folds, faults, etc. The location of all photographs should be noted and marked on a topographic map. A bulletin board can be displayed which shows the map, photographs, and samples.

   Geologic Structure--Determine the strike and dip of strata. Record rock type, features, such as ripple marks, vesicules, concretions, fossils, minerals, and, if possible, thicknesses of strata.

2. Mining and/or Fabrication Area--any quarry, brick factory, ore processing plant, or cement factory can be examined in terms of:

   Economics--plant or quarry size; number of employees; payroll; cost of mining or producing one ton of material; grade of ore; waste disposal; etc.

   Geology--source of deposit; geologic history of deposit; history of mining operations; quantity of ore left; method of extracting metal from the ore; etc.

   Production--is the ore fully processed at this plant; where did it come from; where does it go from here; what types of transportation are used; etc.

Field Trip Three: Sculpture of the Land

1. Reservoir Site--A visit to a reservoir (dam site or open lake) can yield a large amount of information in a relatively short period of time. This site may be examined in terms of:

   Mechanics--cost of construction; sporsoring agency; lake area; lake volume; range of water level fluctuations; watershed area; etc.

   Geological Setting--what is the basement rock; are there problems of water leakage; is there reservoir silting; what are the gradients of the inlet streams; how is water discharged; what is the gradient of the discharge streams;

   Biological Considerations--what types of life exist in the reservoir; is fishing allowed; when the dam was constructed how much land was submerged; what types of vegetative cover are found in the watershed; etc.

2. Road Construction Site--Man constantly scars the landscape with his road building activities. Have a road engineer illustrate examples of road foundations used as the road runs from areas of bedrock, to sections founded on glacial till, stream terraces, former swamp areas. What is the difference in cost for foundations in each type of area.

3. Cemetery--Note the conditions of various gravemarkers as a result of weathering. To quantify the activity, take photographs of gravemarkers, record tombstone dates and the depth of inscription.

4. Glacial Area--Travel through a glaciated area offers a variety of landforms, although quantitative studies are at a minimum.

   Varve Deposit--Count the layers in an exposure; take samples back to the laboratory for microscopic analysis; what is the difference in composition of the dark and light areas in the varve deposit; is this clay used by a brick factory, pottery makers, art classes; look for concretions in the clay; mark the location of the deposit on a topographic map.

   Erratics--Collect rock samples in a gravel pit; compare these rocks to the bedrock of the area; look for glacial striations; note the badly weathered samples and identify the decaying minerals.

   Leaching--Climb the face of a gravel exposure, and collect soil samples at various depths from the top of the pit. Record the depth of each sample taken. In the laboratory, examine the soil and determine pH, phosphorous, potassium, and nitrate content. Soak each sample in distilled water, and then determine the dissolved solids in the water sample. Make charts which relate the depth of the soil versus the parameters measured.

   Soils--Collect soil samples from roadcuts, pastures, and farm fields. Ask permission before entering private property to obtain samples. The land owner may be able to tell the class about the use of his land, fertilizers used, etc. Note the erosional influence of the wind and water on various areas.

5. Sea Coast or Large Lake--Quantitative studies are hard to make when visiting the coast, but qualitative studies are large in number.

   Waves--Count the period of the waves, and compute velocity, wave-length. Estimate the height of the waves as they begin to steepen.

   Water Samples--Collect water samples at various depths and positions along the beach. Compute the amount of dissolved and suspended solids in the sample.

   Beach Sand--Collect beach samples from the low tide mark to the back beach area. Examine under a microscope. Dig into the beach and collect samples at depth.

   Man's Influence--Observe wave behavior near jetties, groins, and breakwalls. Note beach shape in these areas. This is ideal for photographic study.

   Beach Evolution--Obtain maps of the region which were made 20 to 50 years ago. What changes in the shape of the coast are noted. Hypothesize why such changes occurred.

   Pollution--Examine areas where streams empty into the ocean. Collect water samples from this stream and test for dissolved oxygen, carbon dioxide, dissolved solids, pH, phosphates.

6. Aerial Survey--For less than $5.00 per student many airlines will allow a class to charter a plane for several hours. This will allow a class to cover a large area and view a variety of geologic provinces from a vantage point unique to their previous experience.

BIBLIOGRAPHY

1. Andersen, N. D. "Summer Institutes in Earth Science at North Carolina State University," Journal of Geological Education. 17:191-193, December, 1969.

2. Arnold, Luther A. "The Development of a General Education College Chemistry Course." Doctoral dissertation, Gainesville: University of Florida, 1955.

3. Ausubel, D. P. "In Defense of Verbal Learning," Education Theory. 11:15-25, January, 1961.

4. Bailey, D. W. "The Student is the Curriculum at Black Mountain," The Curriculum of Democratic Education, ed. C. C. Peters. New York: McGraw-Hill Book Company, Inc., 1942, pp. 225-226.

5. Barr,D. "The Colleges' Crisis of Integrity: A Headmaster's View," Improving College Teaching, ed. C. B. T. Lee. Washington, D. C.: American Council on Education, 1967, pp. 373-381.

6. Beebe, W. B. "The Potential of ESCP," Geotimes. 12:9, December, 1967.

7. Belanger, M. "Learning Studies in Science Education," Review of Educational Research. 39:377-395, October, 1969.

8. Boyer, R. E. and Snyder, J. L. "Teachers of Earth Science," Geotimes. 8:13-16, March, 1964.

9. _____. "Earth Science Gains Momentum in Secondary Schools," Journal of Research in Science Teaching. 4:43-45, March, 1966.

10. Brandwein, P. F., et al. Teaching High School Science: A Book of Methods. New York: Harcourt, Brace & Co., 1958.

11. Bryan, A. H. "Geology Interest Tests for High School Seniors," School Science and Mathematics. 50:36-39, January, 1950.

12. Burnett, R. W. "New Concepts in the Education of Science Teachers," Journal of Research in Science Teaching. 1:64-72, March, 1963.

13. Carl, J. D. "The Questionable Rules of Classification in Introductory Earth Science," Journal of Geological Education. 13:47-49, April, 1965.

14. Carleton, R. H. "Science Education in Middle or Junior High School Grades," The Science Teacher. 34:25-28, December, 1967.

15. Combs, A. W. The Professional Preparation of Teachers--A Perceptual View of Teacher Preparation. Boston: Allyn & Bacon, Inc., 1965.

16. Combs, A. W. and Snygg, D. Individual Behavior--A Perceptual Approach to Behavior. New York: Harper & Brothers, 1959.

17. Dickson, C. W. "A Functional Approach to and the Preparation of a Laboratory Manual for Undergraduate General Education College Chemistry." Doctoral dissertation, Gainesville: University of Florida, 1969.

18. Digman, R. E. "Geologic Education in Secondary Schools of New York State: Difficulties and Suggestions," Journal of Geologic Education. 1:30-34, April, 1953.

19. Doll, R. C. Curriculum Improvement: Decision-Making and Process. Boston: Allyn & Bacon, Inc., 1964.

20. Drummond, Jr., A. H. "Learning and the Sciences," School Science and Mathematics. 67:125-131, February, 1967.

21. Dutton, W. H. and Stephens, L. "Measuring Attitudes Toward Sciences," School Science and Mathematics. 63:43-49, January, 1963.

22. Eiss, A. F. "The NSTA Conferences on Scientific Literacy," The Science Teacher. 35:30-32, May, 1968.

23. Engman, W. D. "Behavioral Objectives: Key to Planning," The Science Teacher, 35:85-87, October, 1968.

24. Esler, W. K. "Do Real Differences Exist Between Old and New Curricula?" Science Education. 53:67-70, February, 1969.

25. ESTP #3, Earth Science Curriculum Project Newsletter. Boulder, Colorado: January, 1970.

26. Faunce, R. C. and Bossing, N. L. Developing the Core Curriculum. Englewood Cliffs, New Jersey: Prentice-Hall, 1958. Second edition.

27. Featherstone, W. B. A Functional Curriculum for Youth. New York: American Book Company, 1950.

28. Flawn, P. T. "The Environmental Geologist and the Body Politic," Geotimes. 13:13-14, July-August, 1968.

29. Foose, R. M. "Geologic Education," Geotimes. 1:9, December, 1956.

30. Fraser, D. M. Deciding What to Teach. Washington, D. C.: National Education Association, 1963.

31. Funkenstein, D. H. "What Does Higher Education Need to Know About the Student in Today's Changing Society?" Current Issues in Higher Education, ed. G. K. Smith. Washington, D. C.: Association for Higher Education--A Division of NEA, 1960, pp. 160-164.

32. Gega, P. C. "The Pre-Service Education of Elementary Teachers in Science and Teaching of Science," School Science and Mathematics. 68:11-20, January, 1968.

33. Glenn, W. H. "Conceptual Ideas of Geology Included in Secondary School Earth Science Textbooks," Science Education. 54:27-30, January-March, 1970.

34. Good, C. V. Dictionary of Education. New York: McGraw-Hill, 1959.

35. Goodlad, J. E., et al. The Changing School Curriculum. New York: The Foundation for Advancement of Education, 1966.

36. Grobman, S. "Status Study of Schools Teaching Earth and Space Science in Pennsylvania 1965-1966," ERIC. ED 018-358. September, 1968, p. 129.

37. Hagner, A. F. and Henderson, D. M. "Problems in Geologic Education--The Elementary Course," Journal of Geological Education. 7:36-39, Spring, 1959.

38. Hass, G. and Wiles, K. Readings in Curriculum. Boston: Allyn & Bacon, Inc., 1965.

39. Heller, R. L. "The Earth Science Curriculum Project," Journal of Research in Science Teaching. 1:272-275, September, 1963.

40. Hendrix, T. E. and Fox, W. T. "Experimental Approaches to the Introductory Geology Course," Journal of Geological Education. 13:137-142, December, 1965.

41. Hines, S. H. "A Study of Certain Factors Which Affect the Opinions of Elementary School Teachers in the Teaching of Science," ERIC. ED 024-583. April, 1969, p. 93.

42. Holmes, C. D. "Geology and Liberal Education," Journal of Geological Education. 17:142-144, October, 1969.

43. Horn, F. H., et al. "To What Extent Should Faculty, Administration, Trustees, Students, Federal Government, Accrediting Bodies and Others Control the Curriculum?" Current Issues in Higher Education, ed. G. K. Smith. Washington, D. C.: Association for Higher Education--A Division of NEA, 1960, pp. 51-54.

44. Hurd, P. D. New Directions in Teaching Secondary School Science. Chicago: Rand McNally & Company, 1969.

45. Ivey, M. L. "Geology for Florida Junior Colleges." Doctoral dissertation, Gainesville: University of Florida, 1961.

46. Keller, W. D. "On Teaching and Learning," Journal of Geological Education. 16:13-15, February, 1968.

47. Kendall, D. L. "Earth Science in Connecticut Secondary Schools," Journal of Geological Education. 16:178-180, December, 1968.

48. Kent, H. C. "Geology Institutes and the Training of Secondary School Science Teachers," Geotimes. 7:13-14, May-June, 1963.

49. Kline, Jr., L. E. "Textbook Readability and Other Factors Which Could Influence the Success of the Eighth Grade Earth Science Course in the Texas Public Schools," ERIC. ED 011-505. October, 1967, p. 52.

50. Koelsche, C. L. "Scientific Literacy in the Sixties," ERIC. ED 011-843. November, 1967, p. 73.

51. Krug, E. A. Curriculum Planning. New York: Harper & Brothers, 1957.

52. Lacey, A. L. Guide to Science Teaching in Secondary Schools. Belmont, California: Wadsworth Publishing Company, Inc., 1966.

53. Leet, L. D. and Judson, S. Physical Geology. Third edition. Englewood Cliffs, New Jersey: Prentice-Hall, 1965.

54. MacDonald, J. B. "A Curriculum Rationale," Contemporary Thought on Public School Curriculum. Dubuque, Iowa: Wm. C. Brown Co., Publishers, 1968.

55. Matthews, W. H. "Growth of Earth Science in Secondary Schools," School Science and Mathematics. 63:637-646, November, 1963.

56. _____. "Earth Science in Secondary Schools," Geotimes. 13:14-16, March, 1968.

57. Mayer, V. J. "Criterion Model of an Earth Science Teacher Preparation Program," Science Education. 51:290-292, April, 1967.

58. Merrill, W. M. "Purposes of Undergraduate Degree Programs in Geology," Journal of Geological Education. 13:67-70, June, 1965.

59. Merrill, W. M. and Shrum, J. W. "Planning for Earth Science Teacher Preparation," Journal of Geological Education. 14:23-25, February, 1966.

60. Migaki, J. "The Alphabet Game (TAG)," The Science Teacher. 36:55-56, April, 1969.

61. Montague, E. J. and Butts, D. P. "Behavioral Objectives," The Science Teacher. 35:33-35, March, 1968.

62. Moss, J. H. "The Teacher Problem in High School Earth Science Courses," Journal of Geological Education. 2:41-44, June, 1962.

63. _____. "Revision of the Pennsylvania Earth and Space Science Courses," Journal of Geological Education. 16:184-185, December, 1968.

64. Newport, J. F. "Do Teachers Really Want Science Equipment?" Journal of Research in Science Teaching. 4:171-172, September, 1966.

65. Nicodemus, R. B. "Science Curriculum Implementation: A Problem of Teachers and Schools," Science Education. 49:385-388, October, 1965.

66. Orgren, J. R. "Earth Science: Then and Now," Journal of Geological Education. 17:179-183, December, 1969.

67. Parker, J. C. and Rubin, L. J. "Process as Content," Contemporary Thought on Public School Curriculum. Dubuque, Iowa: Wm. C. Brown Co., Publishers, 1968.

68. Pollock, A. W. "Earth Science in New Jersey," Journal of Geological Education. 16:180-183, December, 1968.

69. Rogers, J. W. "Some Thoughts on Professionalism," Journal of Geological Education. 16:132-134, October, 1968.

70. Romey, W. D. "A Strategy for Alleviating the Shortage of Earth Science Teachers," Journal of Geological Education. 14:89-90, June, 1966.

71. _____. "The Need in Introductory Geology Courses," Journal of Geological Education. 17:193-195, December, 1969.

72. Roth, R. A. "Earth Science and Ohio," Journal of Geological Education. 17:185-187, December, 1969.

73. Saylor, J. G. and Alexander, W. M. Curriculum Planning for Modern Schools. New York: Holt, Rinehart, and Winston, 1966.

74. Shamos, M. H. "The Role of Major Conceptual Schemes in Science Education," Readings in Science Education for the Secondary School, ed. H. O.Anderson. New York: The Macmillan Co., 1969, pp. 296-304.

75. Shea, J. H. "Highlights of 1965 ESCP Survey of Earth Teachers," Journal of Geological Education. 14:9-12, February, 1966.

76. Skinner, Jr., R. and Davis, Jr., O. L. "Preparation of Earth Science Teachers in Ohio," Journal of Geological Education. 13:85-86, June, 1965.

77. Snyder, J. "Quotes from Visiting Scientists," Geotimes. 9:16, October, 1964.

78. _____. "Why Major in Geology? Students Answer," Geotimes. 14:13-14, April, 1969.

79. Socolow, A. A. "Bread and Butter Courses May be Fattening," Journal of Geological Education. 6:1-2, Fall, 1958.

80. Spears, H. The Teacher and Curriculum Planning. New York: Prentice-Hall, 1951.

81. Stone, D. B., et al. "Explosive Development of Earth Science Courses," Geotimes. 7:13-19, October, 1962.

82. Sund, R. B. and Trowbridge, L. W. Teaching Science by Inquiry in the Secondary School. Columbus, Ohio: Charles E. Merrill Books, Inc., 1967.

83. Sutton, T. C. "Teacher Failure in Science Teaching," School Science and Mathematics. 44:549-553, May, 1944.

84. Tanner, W. F. "The 'Student Model' Approach to Geology in the Secondary School," Journal of Geological Education. 12:49-53, June, 1964.

85. TIME. "Environment," 95:56-62, February 2, 1970.

86. Umstattd, J. G. College Teaching Background, Theory, Practice. Washington, D. C.: The University Press and the Community College Press, 1964.

87. Victor, E. "Why are Our Elementary School Teachers Reluctant to Teach Science?" Science Education. 46:185-192, March, 1962.

88. Vineyard, J. D. "Blue Collar Science," School Science and Mathematics. 70:222-229, March, 1970.

89. Washton, N. S. "What Should be the Subject Matter Competency of Science Teachers?" Science Education. 40:392-395, December, 1956.

90. _____. Teaching Science Creatively in the Secondary Schools. Philadelphia: W. B. Saunders Co., 1967.

91. Watson, F. G. "Curriculum Design in Science," The Science Teacher. 50:13-16, March, 1963.

92. Welch, W. W. "The Impact of National Curriculum Projects: The Need for Accurate Assessment," School Science and Mathematics. 68:225-235, March, 1968.

93. Westmeyer, P., et al. "A Comparison of Various Techniques for the Dissemination of a New Science Curriculum in Florida," ERIC. ED 010-632. July, 1967, p. 13.

94. Whitcomb, L. "The Elementary Course Textbook Dilemma," Journal of Geological Education. 3:58-60, Fall, 1955.

95. Wicke, M. F. "Criteria for Governing Curricula Content," Current Issues in Higher Education, ed. G. K. Smith. Washington, D. C.: Association for Higher Education--A Division of NEA, 1964, pp. 200-203.

96. Wood, R. L., et al. "Scientifically and/or Technologically Oriented Articles in Selected Newspapers," Journal of Research in Science Teaching. 5:151-153, June, 1967.

BIOGRAPHICAL SKETCH

Michael Bernard Leyden was born February 22, 1940, at Batavia, New York. In June, 1957, he was graduated from Attica High School, Attica, New York. He received his Bachelor of Education degree with a major in general science from State University, Brockport, New York, in June, 1961, and during the following three years was employed by the City School District of Batavia, New York, as a junior high school science teacher. He received a New York State Science Scholarship during the summer of 1962 to attend State University, Oneonta, New York. He also completed science study at State University, Buffalo, New York, and State University, Brockport, New York, while teaching at Batavia.

Financed by a National Science Foundation grant, Mr. Leyden participated in the Academic Year Institute in Earth Science at the University of Florida during the 1964-1965 academic year and received a Masters of Education degree with a major in earth science in August, 1965.

As an instructor in physical science at State College, Westfield, Massachusetts, from 1965 to 1968, he taught geology, astronomy, and physical science.

A grant from the National Science Foundation allowed him to participate in the Smith College In-Service Chemistry Institute at Northampton, Massachusetts, during the 1966-1967 academic year.

Subsequent grants from the National Science Foundation provided study in the "Geology of Mississippi Sound" at the Gulf Coast Research Laboratory, Biloxi, Mississippi during the summer of 1967; "Gulf Coast Geology" at Rice University, Houston, Texas, during the summer of 1968; and "Geochemistry-Geophysics" at the Southwest Center for Advanced Studies in Dallas, Texas, during the summer of 1968. He also completed courses at State College, Westfield, Massachusetts, during the 1965-1968 period.

From September, 1968, to the present time he has completed his studies for the Doctor of Education degree with a major in earth science at the University of Florida. Under the direction of Dr. Ira J. Gordon, he has worked as a graduate assistant in the Early Stimulation Project for the past two years.

Married to the former Margaret Rose Adolf, he has a four year old son, Andrew Parker, and a two and a half year old daughter, Margot Elizabeth.

This dissertation was prepared under the direction of the chairman of the candidate's supervisory committee and has been approved by all members of that committee. It was submitted to the Dean of the College of Education and to the Graduate Council, and was approved as partial fulfillment of the requirements for the degree of Doctor of Education.

August, 1970.

B Sharf & M C Butler

Dean, College of Education

Dean, Graduate School

Supervisory Committee:

Chairman